COMMON COMMODITIES AND INDUSTRIES

GAS AND GAS MAKING

W. H. Y. Webber

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W. H. de. Manning

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A VIEW IN THE LARGEST GASWORKS IN THE WORLD

PITMAN'S COMMON COMMODITIES AND INDUSTRIES

GAS & GAS MAKING

GROWTH, METHODS AND PROSPECTS OF THE GAS INDUSTRY

BY

W. H. Y. WEBBER

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PREFACE

THE purpose of this little book is to give a plain, succinct account, in non-technical language, of the industry of Coal Gas Manufacture and Public Supply. This industry is just over 100 years old, and is of British origin and upbringing. Nothing in all industrial history is more wonderful than the development of what was originally merely a system of extracting and distributing a means of producing a cheap and convenient artificial light, into what Lord Moulton recently described as one of the vital resources of the nation, which has rendered inestimable service in the present emergency. The gas industry claims to be the most economical agency for realizing and applying in the service of man the great potentialities of coal; and the Author of this book trusts that he has succeeded in explaining faithfully and intelligibly, in some measure at least, how this is done. He desires to acknowledge the helpful loan of illustrative matter by gas engineers, amongst whom are Mr. Alwyne Meade, the Author of *Modern Gasworks Practice;* Messrs. Humphreys & Glasgow, Ltd.; the K. & A. Water Gas Co., Ltd.; British Coke Ovens, Ltd.; Messrs. E. G. Appleby & Co., Ltd.; James Keith, Blackman & Co., Ltd.; Wilsons & Mathiesons, Ltd.; The Richmond Gas Stove & Meter Co., Ltd.; Fletcher, Russell & Co., Ltd.; The Woodall, Duckham Co., Ltd.; and the Publishers of *The Gas World.*

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GAS AND GAS MAKING

CHAPTER I

THE NATURE AND ORIGIN OF THE GAS INDUSTRY

THE gas industry is one of the great agencies of public service which contribute so much to the ease, comfort, and security of modern town life. Like others, it is usually taken for granted, seldom praised, and little understood. Yet it is difficult to appreciate the extent and ramifications of the loss of efficiency and convenience which cessation of the customary gas supply would inflict upon a town population. The gas industry does not impress the popular imagination like electricity supply; for whilst the real importance of the interests concerned in the former and the economic value of the services it renders are commonly overlooked, the applications, and still more the potentialities of the latter, receive the admiration proverbially bestowed upon the mysterious and the unfamiliar.

Popular science has scarcely risen to the conception of the idea of ENERGY in the manifestations of motive force, which not only makes all wheels go round, but also compels variation of sensible temperature, and lights all lamps. Apart from such natural forms of energy, convertible for man's needs, as the winds, tides, and falling water, the only source of mechanical power, strictly so called, is the energy of combustion. So far as the United Kingdom and other coal-yielding regions of the earth's surface are concerned, this mineral

and its congener of more restricted localization and production—petroleum—is the chief source of such energy, under the classification of Fuel. Coal, or oil, must itself be treated by heat in some way, in order to set in action its potential energy. When burnt in air for its heating power alone, indirectly, the coal disappears in gaseous products of combustion—carbonic acid gas and water vapour, and only ash remains.

There are two other ways of treating coal besides that of direct and complete combustion—one is by incomplete combustion with restricted air supply to the fire, resulting in the production of a combustible gaseous mixture, called "Producer Gas"—and the other by what is called *carbonization*, or distillation, in a retort exteriorly heated, without admixture of air: this is the method of the gas industry, so called.

The ancestry of the gas industry is particularly clear. A Scots mechanic, Murdoch by name, whilst employed at his trade in the Cornish mining district of Redruth, in the later years of the eighteenth century, amused himself by distilling small quantities of coal in an iron pot and collecting the inflammable air driven off in bladders, which he carried about with him to light his way in the dark lanes—to the alarm of the country folk, who took him for a sort of "Jack o' Lantern." Later the device was improved and systematized by the same Murdoch, who lived to apply his invention to the lighting of many large mills and private buildings in England. Early in the nineteenth century, one Winzer, anglicized into Winsor, a Moravian, promoted a scheme for manufacturing and supplying coal gas from a central station, which resulted in 1813 in the formation of the first gas company, the forerunner of the present Gas Light and Coke Company, London.

The gas industry, thus started with works situated in Westminster, quickly spread throughout the United Kingdom, and some years later was established in every large city of Europe, always upon the same model. The primitive system of manufacture could not vary in essentials. It was necessarily based upon the Retort, as the unit of carbonization, with the necessary elements for purification and magazinage. Distribution involved a system of mains, with service pipes connecting these with the consumer's premises. The gas light was at first a simple jet of flame from the end of a pipe, which was at least five or six times as luminous as the tallow candle or train oil-lights of the period, and was cheaper. Hence the early promise of the new illuminant proved a sufficient inducement to perseverance, in the struggle against the difficulties of creating a new industry of so unprecedented a character, that the very elements of the necessary manufacturing and distributing plant had to be found as they were required. There was nothing in the markets of the period to meet the requirements of the gas industry, beyond the coal and the raw materials of construction. Even the tools to make the gas engineer's indispensable equipment were not in existence; and there was no trained labour to be had for a purpose condemned as unpatriotic by the threatened lighting trades, and ridiculed by the authorities on the sciences of the age.

Gas manufacture owed nothing to the lights of science of the period—rather the contrary, for the Royal Society imposed upon the company, which had its works in the vicinity of the Houses of Parliament, the obligation to shut up its gasholders within strong brick buildings, and did nothing to lighten its struggles with the chemistry and physics of its uncharted adventure. Certainly, the pioneers in the case had no

academic qualifications, and they fell into errors innumerable which excited the amused contempt of their betters in culture ; but they had a good thing in hand, and they stuck to it through thick and thin. So the gas industry grew and multiplied.

CHAPTER II

GAS SUPPLY AS A PUBLIC SERVICE UNDERTAKING

ALTHOUGH the essentials of gas manufacture were grasped very early in its history, and the lighting of particular establishments upon the lines developed by Murdoch presented no insuperable difficulties, it proved to be another matter to found a paying business in public gas supply. The private manufacturer had only his own capital outlay and running expenses to consider ; but over and above the material shortcomings in respect of means of general distribution already alluded to, there arose troublesome questions as to methods of charging for the public supply service, and the measures to be taken for assuring the continuity and quality of the light. The expedient adopted and followed for a number of years was that of contract for the use of the light for so many hours an evening at a fixed rental, the company engaging to maintain flames of a certain size. This system gave rise to many disputes, and it was a great relief to both parties when the consumer's gas meter was invented, and the sale of gas based upon measurement.

It would be foreign to the scope of this little book to detail the reasons for placing the gas supply of British towns under statutory control by general and special Acts of Parliament, or to set out at length the provisions so enacted. It was recognized from the first beginnings of the public gas supply service of the Metropolis, that undertakings requiring the use of the subsoil of the streets for private gain should in return be subjected to reasonable obligations conceived in the interests of public safety, the avoidance of nuisance,

and fair treatment of consumers. Therefore, statutory gas companies were restricted to a maximum price for their gas, and maximum dividends for their shareholders, whilst the quality of the supply was defined in terms and safeguarded by requirements calculated to ensure their customers getting gas of the illuminating power, purity, and pressure covenanted for. Originally, competition in the business was welcomed for the sake of the benefits to trade proverbially ascribed to it; but eventually this was proved to be a mistake in regard to gas supply, and a substitute was found in throwing open the companies' capital issues to public auction or tender, coupled with the institution of a standard price for gas at which the statutory dividends might be paid, if earned during the account period: subject to the provision that in the event of the actual selling price of gas having been reduced for such period below the standard price, a certain addition to the rate of dividend might be distributed; and *vice versâ*. The design of this arrangement is obviously to make it to the advantage of the gas company to reduce the price of gas to the lowest possible figure consistent with solvent working, by the inducement of an increase of dividend thereby permitted. Incidentally, the healthy rivalry thus fostered in the British gas industry has thrown the field open for the adoption of progressive administrative methods, and the introduction of economies and improvements in its conduct which have kept it abreast of the contemporary technical movement. From its crude beginnings as a purveyor of the illuminating gas obtained by retorting bituminous coal, with insignificant side-lines in the residual coke and coal tar, the industry has arrived at the position of being the most economical user of the national coal capital, which it converts into the strongest known

artificial combustible gas—yielding incidentally a cheap and brilliant means of illumination; but of equal, if not greater, importance as a distributed gasiform fuel, powerful, cleanly, capable of application to a myriad purposes, industrial and domestic; and one of the best sources of mechanical power. Its residual solid fuel, coke, is little inferior in value to the coal from which it is made, and as factory, steam, and house varieties of coal increase in price, will be so treated as to take their places. Its fluid residual product, tar, is the precious raw material of a great organic chemical industry, itself the creation of English genius, by which the world is supplied with dyes, drugs, explosives, etc., in infinite variety. Another by-product, ammonia, is an invaluable soil fertilizer; and is also convertible into a number of indispensable chemical compounds, besides constituting the working element in refrigerating systems. Yet another, cyanogen, is essential to the recovery of gold from its gravels. None of these products was known in the time when the only use made of coal was to burn it for its sensible heat, and all are still wasted and lost when coal, containing these elements, is consumed in domestic fireplaces, in steam boilers, furnaces, or other direct applications of fuel.

For some long time yet coal will doubtless be so burnt, by reason of many considerations which cannot be gone into here. The way of economical progress in respect of work done by artificial heat is, however, clearly indicated, and therefore every fresh advance in this direction is to be welcomed. Where gaseous fuel has once proved advantageous, there is no turning back. It is not solely a question of the expansion of the gas industry, properly so called. A very great deal is being done, and will be extended in connection with the

application of fuel gas produced by the method of gasification with air, of kinds of solid fuel less suitable for carbonization. All this is outside the scope of this book, but mention will necessarily be made incidentally of the employment of producer gas in carbonizing and for other gasworks purposes.

The goal to which the true coal economist should aim is the matter of course consignment of all coal intended to subserve domestic purposes, and in a great measure the needs of manufacturing industries, to the gasworks. Buyers of raw coal for particular requirements should be licensed for definite periods, with liberty to apply again. Thus eventually by the improvement and development of the methods and manufactured products of the gas industry, aided by a gentle pressure from a Coal Control Office, and perhaps a Health Ministry, the atmosphere over England will be cleared of smoke, and every ton of coal consumed in the country will do the work of two or three tons now crudely, wastefully, and stupidly burnt.

CHAPTER III

EARLY METHODS OF GAS MAKING

COAL gas, as has been told, was originally made by heating suitable coal, which must be of the bituminous variety, in a closed and sealed iron pot, provided with a pipe connection at the top to carry off the gas and vapours which arise as a dense, greenish-brown smoke. The residuum after all this had been driven off was coke, which had to be tipped out to make way for a fresh charge. The operation, it will be observed, was intermittent ; and so it has remained in common practice for a hundred years, and appears likely to persist in certain forms of apparatus.

Improvement was not long in giving the retort more convenient forms and dispositions for facilitating the control of the distillation, saving fuel and reducing the labour attending the operation. These objects have been steadily pursued ever since.

The retort became a tube placed horizontally over the furnace, either circular in cross-section, or with a flattened sole, the shape of the letter D, the latter being most favoured by reason of the uniform depth of the layer of coal constituting the charge, which is an advantage. The retort, when of cast iron, could only be raised to a full red-heat, of a temperature of about 1,400° Fahrenheit, the melting-point of the metal being at about 2,000° Fahr. This consideration therefore governed the carbonization process, which usually took from six to eight hours. The retort was never filled because, in course of carbonization, common bituminous coal swells considerably, and would burst the retort unless room were provided for the charge

to rise. Moreover, as the retort was closed at the back end, it was necessary to have space above the coke to allow of the insertion of a rake for drawing the spent charge. These iron retorts were seldom larger than 12 in. or 14 in. diameter by 6 ft. 6 in. long. They were costly and short-lived in consequence of the perishing of the metal.

In course of time, as the scale of gas manufacture grew in magnitude, the need for more economical working prompted the construction of larger carbonizing ovens, built of fireclay, and also of retorts moulded of the same refractory material. The former were comparatively capacious, holding a charge of as much as 10 cwt. of coal, which took 12 hours to work off. Although these ovens were superseded within living memory by the more convenient retorts, which lent themselves to greater economy of ground space by the system of grouping up to as many as ten in a setting, or "bed," heated by a single fire, it is remarkable that the principle of carbonizing coal in mass up to 10 tons, in so-called "chamber" or "retort-ovens" is actually being revived in the latest gasworks practice.

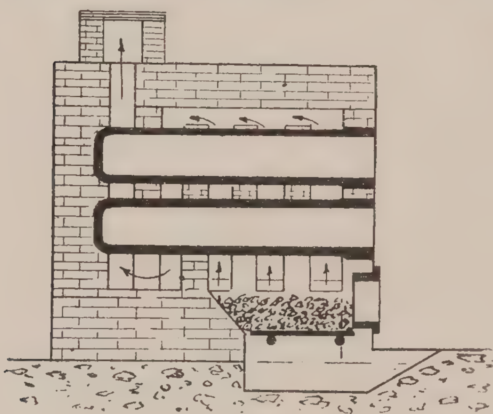

FIG. 1

TYPICAL DIRECT-FIRED RETORT SETTING

It must be borne in mind that at the period now under discussion, and for long after, all gas manufacture was by manual labour. Ovens and retorts alike were charged by shovel; and the work of throwing the

coal to a distance of 10 ft. or so, to the end of the oven or retort, and following this up by shorter pitches up to the front end was both arduous and called for much practice. Uneven layering of the charges caused irregular carbonizing, the thinner portions becoming over-burnt while the heaped portions remained unworked off in the regulation period. In large gasworks a system of retort-setting was adopted in which the retorts were open at each end and about 20 ft. long. These tubular retorts were charged by means of "scoops" introduced at both ends simultaneously. This involved the organized work of a double gang of six stokers, three a side—two to lift the point of the scoop into the retort mouth-piece, and the third to push it in and turn it over, leaving the coal evenly laid from end to end of the retort. The coke would be drawn simultaneously from both ends also.

For many years the above system of gang labour remained characteristic of the best carbonizing working in English gasworks. The dimensions of retorts and their section varied in different places; but the general arrangement was much the same, and a somewhat elaborate routine ruled the work. The gangs of stokers and their attendant firemen worked 12-hour shifts nominally; but the actual labour was not continuous. Gas manufacture being largely a seasonal occupation, a portion only of the carbonizing force remained in constant employment, the extra winter hands finding other engagements during the summer.

Towards the later years of the last century, several important changes began to break into this established routine of gas manufacture, one leading to another, until actually within the last twenty-five years the whole face of the industry has been altered. Some of these changes relate to technic, others to the nature

of the gas business. In order to understand the latter position, a dip into history is necessary ; the former is largely an engineering development, aimed at the substitution of mechanical operation for manual labour, and assisted by the latter changes.

CHAPTER IV

GAS MANUFACTURE: THE MIDDLE PERIOD

It has been stated that coal gas was originally made in iron retorts, at a temperature which may be conveniently distinguished as "low to moderate." The gas was consequently rich in the heavy hydrocarbons which render the flame luminous, being of the character of the paraffin vapour which burns in a candle flame. After the manufacture passed to fireclay retorts, worked at a higher temperature, say, about 1,750° Fahr., the composition of gas became affected. Some of the paraffin vapours were "cracked" into benzoloid compounds, whilst passing along the length of the hot retort over the incandescent coke. The yield of gas per ton of coal was increased, and it became expedient to settle upon a standard of "quality"—meaning the equivalent illuminating value of a fixed quantity of the gas consumed under standard conditions in a standard burner in a certain time—at which the public should be held to be receiving value for money.

This proved to be anything but a simple matter to settle by agreement. After much debate, the following terms were adopted for the 16 candle-power common coal-gas supply of London:—

The standard of light to be that of a spermaceti candle, six to the pound, burning at the rate of 120 grains of sperm per hour. The gas to be burnt at the rate of 5 cubic feet per hour, by means of a certain pattern and size of burner of the Argand type, with chimney; when its light should equal that calculated to be given by sixteen of such candles. In other words,

the illuminating power of 5 cubic feet of common London coal gas was to be not less than sixteen times that of a standard candle.

The term " common coal gas " here means gas manufactured from the ordinary sea-borne Newcastle gas coal which was at the time, and still is the type of raw material best suited to the supply of the Metropolitan and Southern area generally.

The typical London common coal gas of this period—when the supply was intended to be used for lighting only, by the flat-flame burner, had the following approximate composition :—

		Vols. per cent.
Luminous hydrocarbons . .	($C_n H_m$)	5·40
Light carburetted hydrogen .	($C H_4$)	37·90
Carbon monoxide . . .	($C O$)	7·40
Hydrogen	(H_2)	46·44
Nitrogen	(N_2)	2·86
		100·00

This sample represents the result of the best carbonizing practice, with good coal. It was made at the rate of 10,400 cubic feet per ton, and purified with lime. Its illuminating power was seventeen candles.

In course of time the deliveries of common gas coal fell off in quality and it became impossible to make the normal quantity of gas per ton, 10,000 cubic feet, of standard quality, without an increasing addition of the costly " cannel " coal, such as was carbonized in the Edinburgh, Glasgow, and other Scottish gas undertakings. Some English gas companies endeavoured to keep up the quality by dropping the make per ton ; but this proved too costly an expedient, as the price of common gas coal also rose. Eventually the price of cannel coal was forced up to an exorbitant figure,

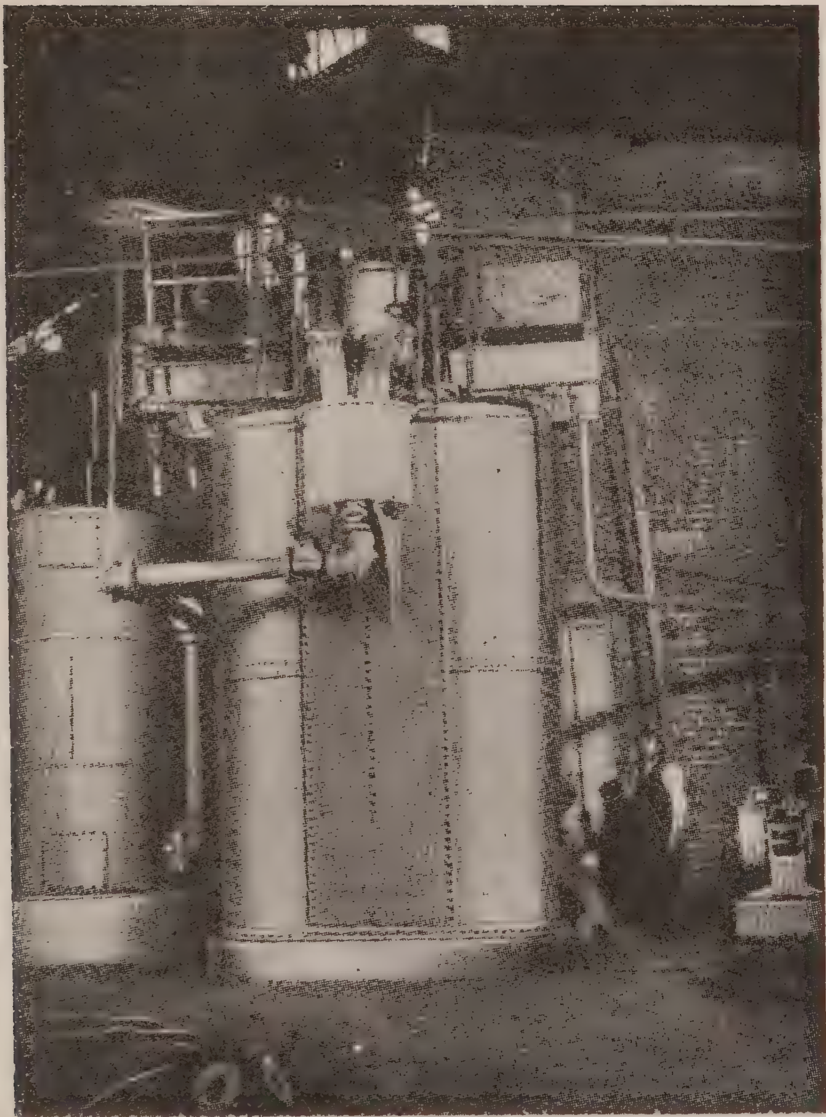

Fig. 2

"BLUE WATER GAS" PLANT (K AND A SYSTEM)

so that it became an imperative necessity to seek an efficient substitute for it. This was found in the "nineties," in carburetted water gas, which had for some years previously constituted the chief gas supply of New York and other American cities.

Carburetted water gas, technically called for short "C.W.G.," was an American improvement upon an old English invention, which had never gained an industrial footing. Strictly so-called "water gas" is obtained by passing steam over red-hot iron. Water being a compound of Hydrogen and Oxygen (H_2O), under suitable conditions of temperature the oxygen enters into combination with the iron, leaving the combustible hydrogen gas uncombined. In practice, a less expensive method is followed in preparing what is called "Blue Water Gas." Anthracite coal, or coke, is blown up by an air blast to a high temperature in a form of cupola, and then the air is shut off, the smoke-stack closed, and steam passed into and through the incandescent fuel, the resultant gas being taken off by a pipe. This gas is a roughly half-and-half mixture of carbon monoxide ($C\,O$), formed from the oxygen of the water in combination with the carbon of the fuel, with the hydrogen (H_2) left over from this reaction. The calorific or heating value of these two gases is, by volume, very nearly the same. This gaseous fuel is rarely used alone for any industrial purpose other than welding metals by the heat of its flame, which is very intense. When, however, mineral oil is injected into the nascent product, to be first vaporized and then fixed as a gas by passing all together through a superheater, the blend is Carburetted Water Gas, a quite permanent luminous gas, the luminosity and calorific power of which can be adjusted over a wide range by varying the proportion of oil. It is quite suitable for

use as town's gas, either alone, as in America, or mixed with coal gas as an enricher or as a bulk addition.

The advantages of such an auxiliary to coal-gas plant suffering from degeneration of the product, are considerable. The C.W.G. manufacturing plant is much cheaper than coal carbonizing plant of equal capacity, it occupies much less ground space, requires far less labour, can be started up or laid off at short notice, and the product can be made of any desired quality at will. As commonly employed in the United States, with anthracite coal and crude native petroleum, gas of twenty-one or twenty-two candle-power was found to be a most satisfactory product. As adopted in England, for enriching coal gas, it was of the following approximate composition :—

		Vols. per cent.
Luminous hydrocarbons . .	($C_n H_m$)	12·5
Light carburetted hydrogen .	($C H_4$)	15·0
Carbon monoxide . . .	($C O$)	33·0
Hydrogen	(H_2)	34·0
Carbon dioxide, etc. . .	($C O_2$)	5·5
		100·0

(*Butterfield.*)

This sample had an illuminating power equal to twenty-six candles.

A less highly carburetted sample showed as follows :—

		Vols. per cent.
Luminous hydrocarbons . .	($C_n H_m$)	8·23
Light carburetted hydrogen .	($C H_4$)	16·88
Carbon monoxide . . .	($C O$)	29·03
Hydrogen	(H_2)	39·44
Nitrogen	(N)	6·21
Oxygen	(O_2)	0·21
		100·00

(*Lewes.*)

The outstanding feature of C.W.G. in which it differs

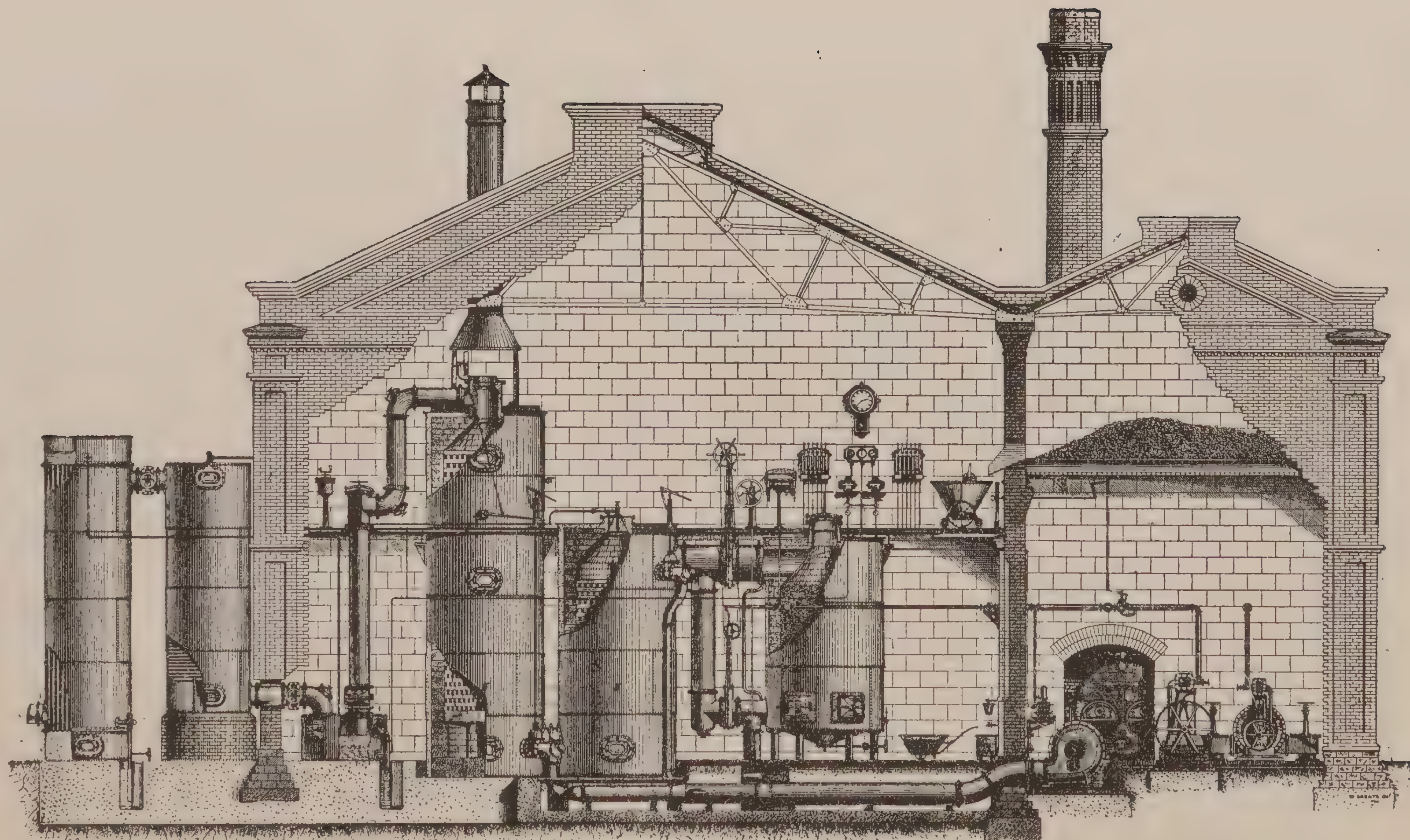

Fig. 3

HUMPHREYS AND GLASGOW CARBURETTED WATER GAS SYSTEM

most conspicuously from coal gas, is the higher proportion of carbon monoxide ($C\,O$). This gas is poisonous, when inhaled by warm-blooded animals, by reason of its specific action upon the red corpuscles of the blood. Consequently strong exception was taken in some quarters to the introduction of C.W.G. as a component of British town's gas. A Government inquiry was accordingly instituted, and it was determined that no sensible risk to the public was incurred when the proportion of $C\,O$ in the gas distributed did not exceed 17 per cent. This means that the addition of C.W.G. to the output should not exceed 40 per cent.; and inasmuch as in ordinary circumstances this product is more costly to manufacture in England than coal gas, such a large proportion has rarely been admitted.

We are now dealing with the subject of enriching the output in order to satisfy the illuminating power requirement of sixteen candles, or thereabouts. Another way of accomplishing this end was by "carburetting" the gas with vapour of benzol, one of the highly luminous burning by-products of high temperature carbonization already existing in the gas as part of the mysterious entry in its analysis ($C_n\,H_m$). More of it is recovered by distillation of the tar, so that it is a quite natural, if roundabout proceeding, to return to its parent source so much as might be required to bring it up to "scratch." The analogous petroleum spirit, "gasoline"—later put to another use by the name of "petrol,"—was also employed for the same purpose.

A keen observer will notice, underlying all this necessity for the artificial enrichment of the town gas of the period in question—the later years of the past century,—how the illuminating power test dominated the gas industry. It is an easy inference from the fact, that one effect was to hamper the development of the

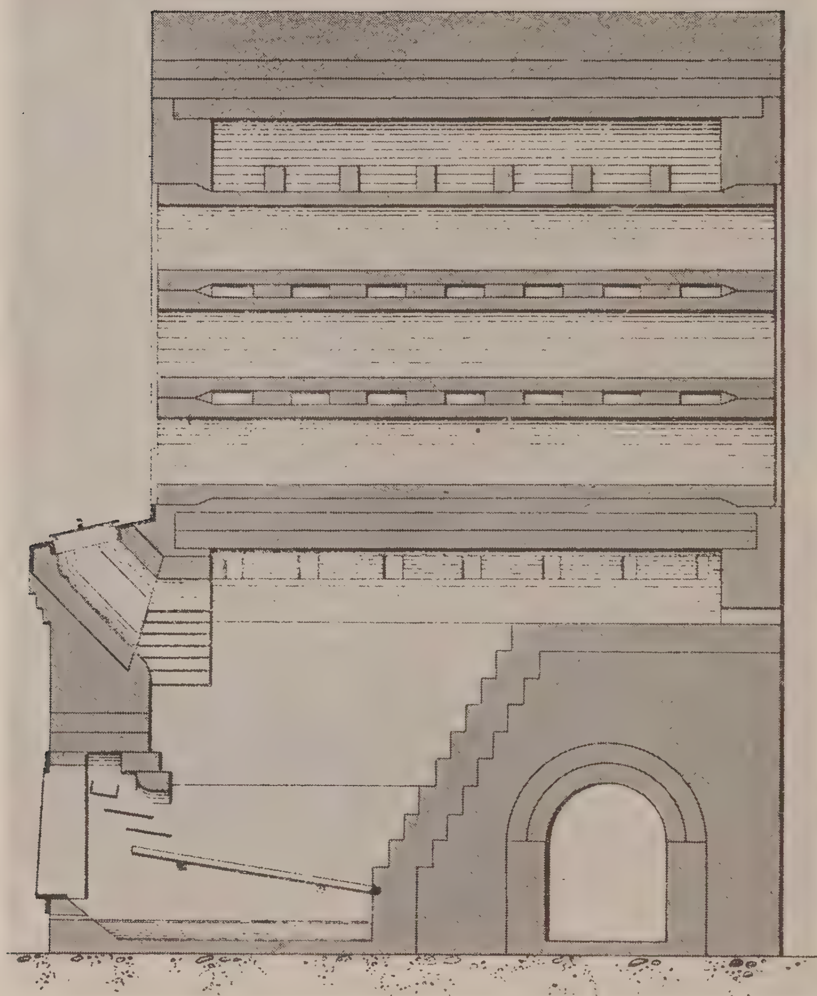

Fig. 4

TEN-FOOT "THROUGH" RETORT BENCH,
WITH GAS-PRODUCER FURNACE

industry along the line of true economy in respect of making the best use of the raw material, coal. During these years of struggle under the burden of a tradition, gas engineering dared not launch out into any tentative which, offering the inducements of a larger yield of gas from the coal carbonized, or of a reduction of the labour and upkeep costs of type plant, might threaten interference with the sacred quality of flame illuminating power. Thus everything hung upon the small percentage in the gas of high illuminants of the benzene series of hydrocarbons ($C_n H_m$), which might on no account be either reduced in quantity nor prejudiced in effect by the companionship of an excessive proportion of non-luminous heat-producing components labelled respectively CH_4, H_2, or CO. Still worse would it be if either of the inert components, carbon-dioxide, nitrogen, or the supporter of combustion, oxygen, rose to anything like a head. The first-named, CO_2, is the most inimical to flame illuminating power. Inasmuch as it is the product of the complete combustion of carbon in air, more or less of it is unavoidable when such combustion takes place, and in the best-managed carbonization process there is some actual combustion, resulting in the appearance in the gaseous product of CO_2, N, and often a little surplus oxygen It is possible to remove most of the CO_2 by the processes of purification through which the gas passes, as will be explained later ; but all these effects are relative.

Meanwhile, about this period certain important movements took place in the ordering of retort-house practice, breaking ground in ways previously closed. A revolution was effected in the method of heating the retorts. Instead of what was known by the name of "direct firing," meaning the burning of the

coke fuel of the retort-setting furnaces to $C O_2$, by a strong chimney draught giving ample access of air, which produced high furnace temperatures—the actual heating of retorts depending upon the circulation through cunningly disposed flues of the hot inert products of combustion—the system of firing by producer gas, with regeneration, was successfully applied to the peculiar requirements of the case. This reformation, which secured important economy of fuel, reduced wear and tear, and better working results—incidentally rendering a Sunday off spell practicable—is an instructive illustration of the danger of imperfect knowledge, leading to a false conclusion. As such, and for other reasons, it is worthy of examination by the aid of data appertaining to the science of Heat.

The British unit of heat measurement, or thermal unit, commonly written B.Th.U., is also conveniently called the "therm." As employed in this book it means the quantity of heat that goes to raise the temperature of one pound of water at about 39° Fahr., which is the temperature of maximum density of water, by or through 1° Fahr. Conversely, when the same weight of water loses 1° Fahr. of temperature, the loss is that of one therm.

The heating power, or calorific value of fuels is measured in therms. per pound, or in the case of gaseous fuels, per cubic foot. Pure carbon, which constitutes 90 per cent. of the weight of coke, when burnt directly to carbon dioxide with the exact theoretic volume of air containing the necessary oxygen, is rated at 14,500 therms. per pound. When burnt to carbon monoxide, the heat developed is only 4,450 therms. per pound. Carbon monoxide burnt to carbon dioxide yields 4,385 therms. per pound. Obviously, therefore, to burn the carbon in these two stages instead of directly

in one, shows a loss of $14{,}500-(4{,}450+4{,}385)=5{,}665$ therms. per pound, or 39 per cent.

This deduction is quite correct ; yet in practice the apparently wasteful proposition is the economical one. In the first place, direct burning produces intense local heat in the furnace, where it is not required for a setting of gas retorts. These can only be reached by circulation of the over-heated gases of combustion ; and because the gases of combustion proper are of insufficient volume to keep the whole setting at the desired temperature, an excess of air must be admitted by means of a sharp chimney draught, which means wasteful combustion. The wear and tear of the furnace is great, and constant attention on the part of the fireman is imperative, both as to stoking and clinkering. After all, the consumption of fuel is considerable, and the results not always correspondingly high. The labour of the fireman in face of the high temperature of the furnace is trying in the extreme.

With the change to retort heating by producer gas, or as it is technically called, gas generator firing, the whole working condition is ameliorated. The gas generator functions at a comparatively mild temperature, and the formation of hard clinker is prevented by the introduction of steam, which goes to form water gas. The fuel gas is burnt within the setting by a secondary air supply, previously heated recuperatively by the waste gases of combustion, the quantity of which can be regulated to great nicety ; and the heat is brought into close proximity to its work. Net result—a marked saving of fuel, and an enormous gain in regularity of heat and ease of working. A not unimportant incidental effect was to place at the command of the carbonizer a system of heating which gave wide play to the scale, shape, and disposition of any elements of

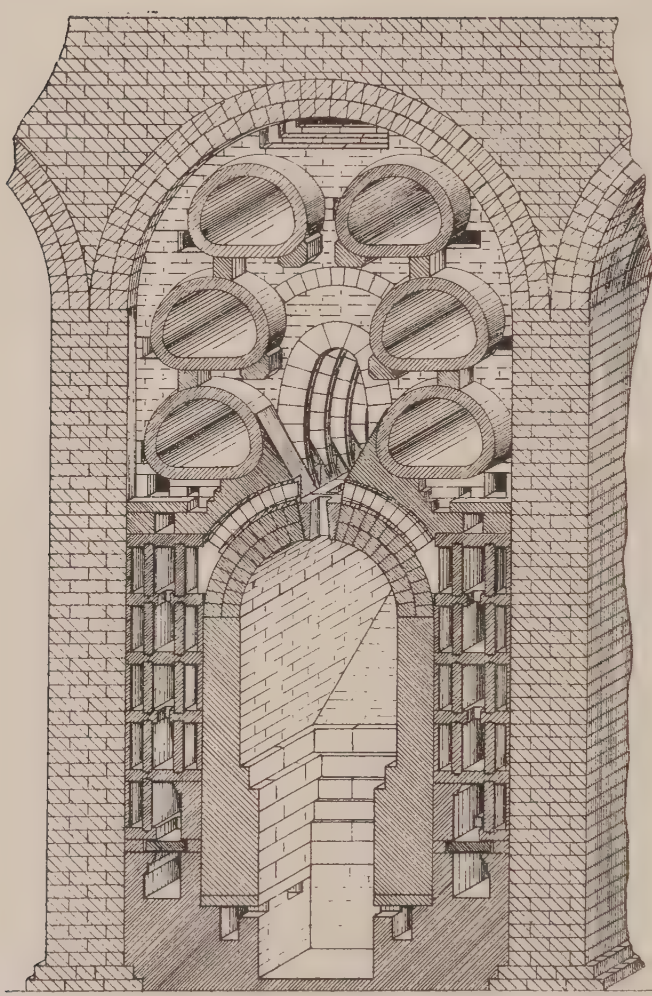

Fig. 5

"WINSTANLEY" RETORT SETTING,
SHOWING REGENERATIVE GAS
FURNACE SYSTEM

construction which might recommend themselves for new and particular reasons.

Another important change in the established retort-house regime was the successful introduction of gas stoking machines, in substitution for manual labour. Gas engineers had from the earliest days harboured a desire to work their carbonizing plant mechanically; but nearly a century was to elapse before the problem was approximately solved. Then, as a matter of course, it found simultaneously several solutions of almost equal excellence. The elements of the problem may be recapitulated as follows :—

First.—Gravity. Coal, weighty yet in no very heavy loads, had to be lifted to the height of the retorts. Before the complete problem was solved, one of the men who eventually solved it, Mr. John West, engineer and manager of the Maidstone, Kent, gasworks, devised tackle for relieving the hand-stoker of the weight of his charges.

Secondly.—Layering the charge evenly in and through the 20-ft. length of a standard "through" retort. The layering, already explained as necessitated by the swelling of the charge in coking, was also recognized as essential to the satisfactory result of high temperature carbonization, by reason of the free space over the charge acting as a reverberatory chamber in which the heavy paraffin vapours rising from the coal were roasted into the higher benzoloid hydrocarbon gases.

Thirdly.—Raking out the hot coke.

Fourthly.—All the preliminary and consequential dispositions filling in the interval between the reception of the coal, and the piling of the coke in the yard.

Fifthly.—Showing a sufficient margin of financial and other advantage to warrant the cost of working-scale experiments, involving risk of expensive failures.

In all inventions there are two stages, the first when the thing is judged to be worth trying, the second when it is worth persevering with despite initial difficulties and disappointments.

One scheme for reducing the manual labour of stoking proposed the setting of retorts, of the usual form and dimensions, at an angle with the horizontal corresponding with the natural slope of repose of heaped coal, namely, 32°. The idea was that if the retort were so tilted, the charge might be shot into it from above the higher end, and if prevented by a stop from falling out at the lower end, would layer itself progressively from the bottom upward to any desired thickness, thus preserving the free space over the charge. The coke might be expected either to fall out of itself, when the lower end of the retort was opened, or yield easily to a gentle push from above. After many trials the system proved sufficiently successful to be accepted as a practical method of carbonizing in many cases, and it is still in operation. Its adoption, however, is not extending, as it has been superseded by better systems.

CHAPTER V

GAS MANUFACTURE: LATER PRACTICE

The immediate impulse which caused gas engineers to definitely open the chapter of the mechanical operation of their retorts was the growing stringency of labour conditions, which came to a head in 1889. There were in that year serious strikes of gasworkers; and these troubles, with the greatly increased cost of working in the traditional style, weighed down the balance in favour of the machines already available, and offered a fair opportunity for improvement in this direction. For some years the requirement of layered charges, and raked-out coke continued to lie heavy on the mechanical engineering of the matter; but these conditions were in due course abrogated by the acceptance of an altogether new criterion of carbonization performance. This was the change of the measure of quality of town's gas from the illuminating power-standard to that of calorific power, brought about in the beginning of the present century by the definite success of the incandescent type of gas light, which was invented by Von Welsbach in 1885. The broad result was to abolish the thin layered charge, as the consequence of the removal of the need for a large benzol production. It was ascertained that the influence of the few and costly illuminative hydrocarbons, very great as regards the self-luminosity of the gas flame, was practically negligible from the point of view of fuel value, which chiefly mattered to the Welsbach light. Hence the door was thrown open to heavier charges in horizontal retorts, up to the point of filling the retort more or less completely by the resultant

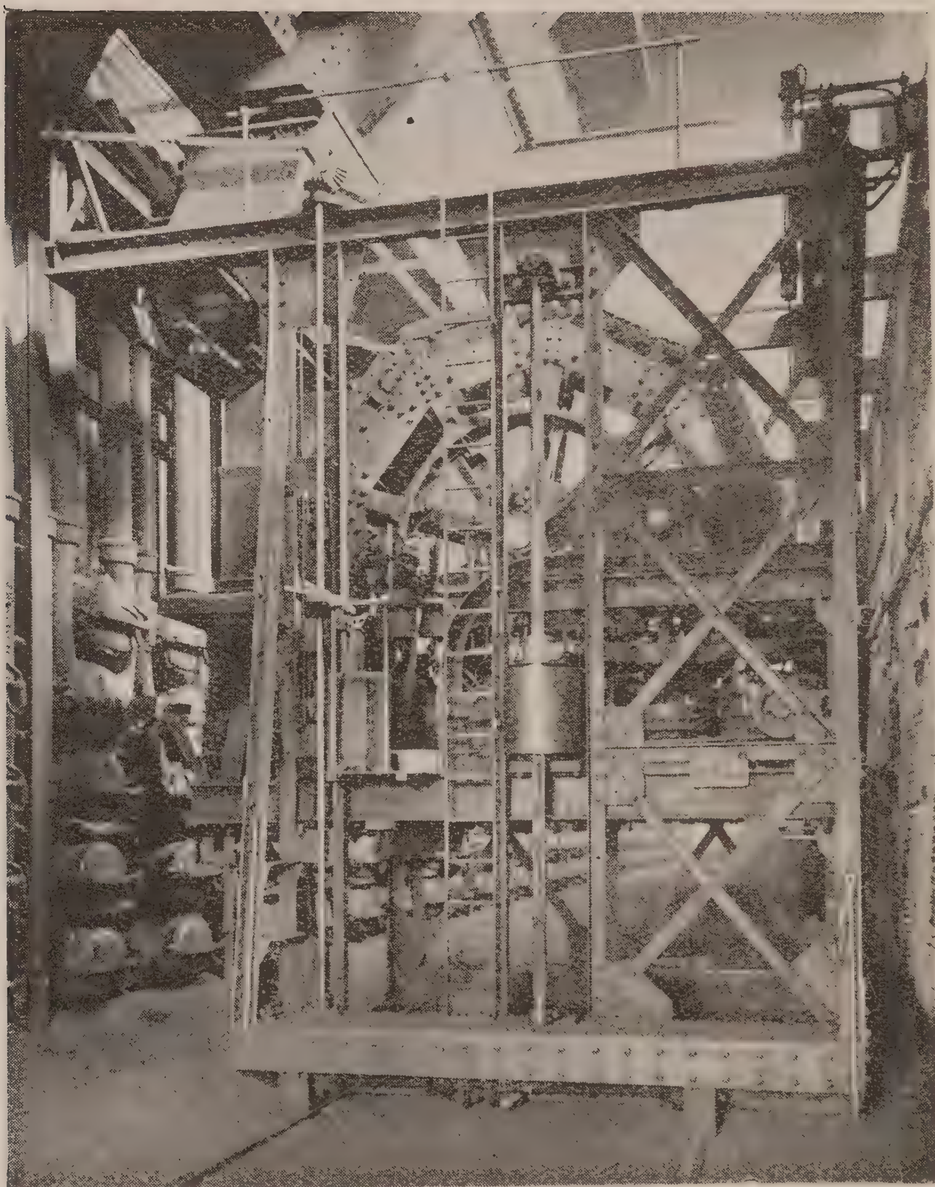

Fig. 6

HORIZONTAL RETORTS WITH STOKING MACHINE

coke, which then lent itself to being pushed out from one end by a power-ram. The possibility of substituting capacious chamber-ovens, holding as many tons of coal as the old style retorts held hundredweights, also dawned upon the gas industry.

Naturally, the modified style of charging and emptying the horizontal retort enormously facilitated the mechanical operations. Machines driven by compressed air, by hydraulic power, and by electricity, had greater scope for proving their advantages; and the progress of mechanical accessories before and after the actual carbonizing process rapidly turned the twentieth century gasworks into a machine station. Meanwhile, an old proposition—the vertical retort, filling and emptying itself by gravity action alone—was revived and took practical shape in two type-forms, distinguished by their systems of operation as the "intermittent" and "continuous" verticals. Really, as might be surmized from what has been told of the beginnings of gas manufacture, the upright kind of retort was the primitive form of the apparatus; but it had been left behind for a hundred years by the horizontal pattern.

Although an upright retort looks a simpler appliance than a horizontal or an inclined tube, in point of fact it has its own difficulties, which proceed mainly from the nature of the material required to be carbonized, and the results of the operation. In the first place, a long, vertical tube is not so easily or so economically heated as a body lying athwart and above the furnace. Until the advent of gaseous firing, this drawback was fatal. Next, the swelling of a coke charge, tending to burst the retort and hang up the coke was another formidable difficulty. Means have been found to deal with the second obstacle, as with the first; and in the

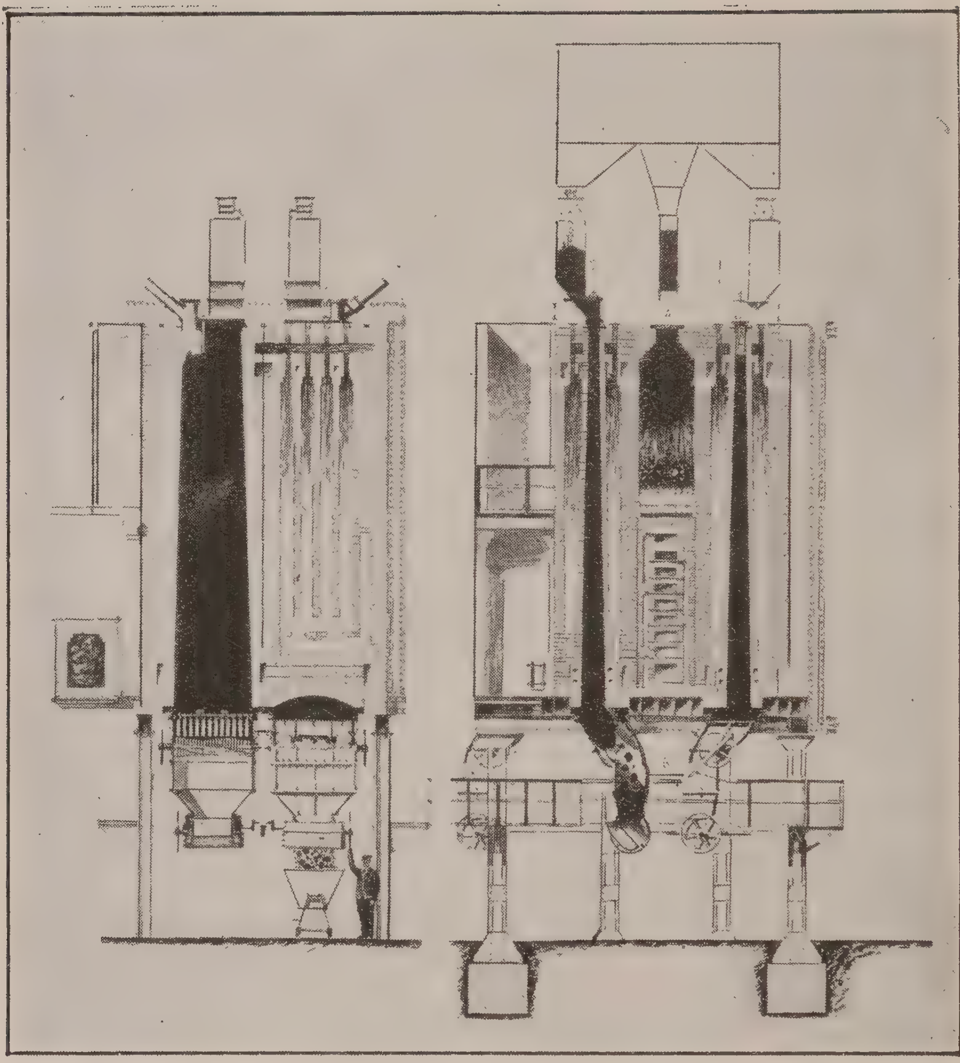

Fig. 7

WOODALL-DUCKHAM CONTINUOUS VERTICAL RETORT SYSTEM

result the undoubted saving of labour due to the vertical type more than sets off the greater structural cost, as compared with the horizontal type. In the intermittent vertical retort, as the name implies, the whole charge of coal is dropped in at once, and remains until completely carbonized, when the coke is dropped out at the bottom and conveyed away for quenching. Not only is the amount of manual labour and skilled attention reduced, but the mechanical operation is also of the simplest character. Wear and tear is slight. One great advantage of the system consists in the facility with which the thermal standard of the gas can be controlled, without interference with the "gait" of the retorts, by the admixture during the latter period of working off of steam which will combine with the coke to produce "blue water gas," with no addition of special generating plant.

The continuous vertical retort is a much more elaborate proposition, which, on account of the obvious risks and difficulties in the way of a successful solution, was long held at arm's length by the most experienced carbonizers. The skilful German engineers who brought to perfection the intermittent vertical retort, upon what is known as the Dessau model—from the place where the idea was worked out,—resolutely refused to take the further step of making the process continuous, judging the possible advantages not worth the trouble. Be this as it may, the endeavour was undertaken by certain English gas engineers, who in course of time accomplished the object of automatic, unintermittent carbonization of bituminous coal not only in a practical way, but also with a degree of economical and other beneficial advantages otherwise unobtainable.

The essential principle of these arrangements is that of wholly mechanical handling of the coal, from its

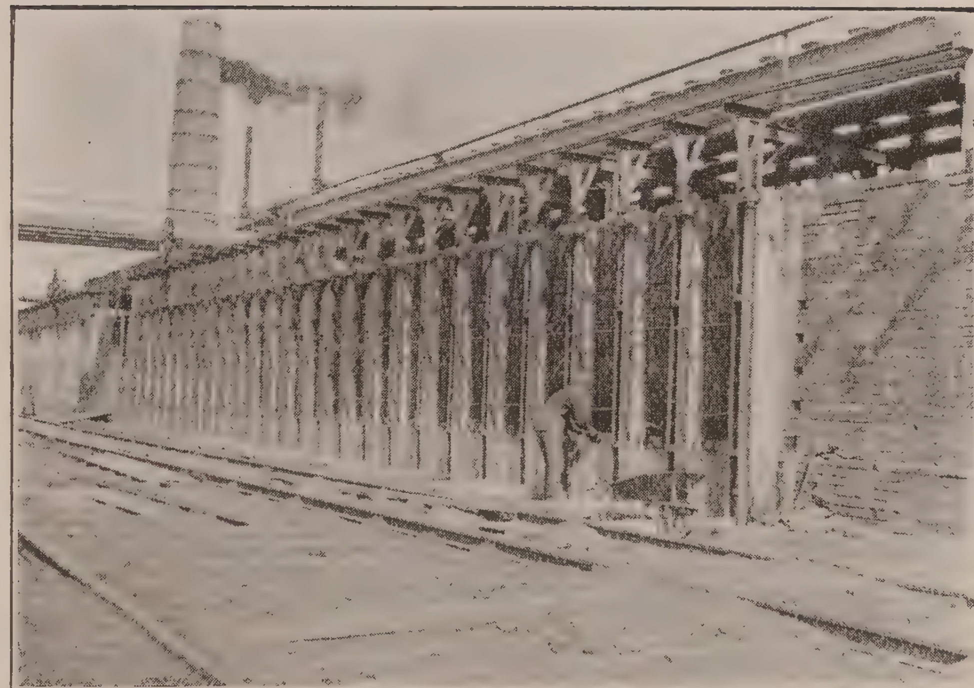

Fig. 8

REGENERATIVE RETORT-OVENS

delivery on the works, to the magazinage of the coke for sale. The actual process of carbonization proceeds automatically. This means that the charge continuously supplied through an air and gas-tight ante-chamber in quantity exactly determined by the rate of carbonization, thereupon descends through the hot zone of the retort, whence the gas is withdrawn. The coke, as formed, must not be unduly broken up into the small pieces classified as "breeze" (cf. *brisé*, French), and must be somewhat cooled by the time it arrives at the bottom of the retort, from which it is extracted at a rate of speed which governs that of the coal feed. In some cases, as remarked above, steam is admitted to make a supplementary bulk of blue water gas. For dealing with a coal which cokes with difficulty, a modified arrangement has been devised which allows the coke to rest *in situ* for a certain period of time, so that it is removed semi-intermittently.

The great advantages of the continuous vertical retort system of carbonization are the reduction of all labour to mere supervision ; a considerable measure of control over the production of gas in respect of quality ; freedom from pipe stoppages and other troubles, and sources of expense inseparable from horizontal retort operation ; and absence of the periodical noises, smoke and steam accompanying the discharge and quenching of large quantities of hot coke.

Possibly, however, the future of coal carbonizing on the largest scale, which will be the natural consequence of the extension of the industrial and domestic use of fuel in the gaseous state and the substitution of coke in some form for raw coal, lies in the direction of mass treatment. The ground has been opened up for some considerable time by the progressive development of the retort-oven principle in metallurgical

Fig. 9

THE KERPELY FUEL GAS PRODUCER

coke manufacture, which has become approximated more and more to the standards of the gas industry. Originally the coking of coal for the use of blast furnaces for the reduction of iron from the ore was conducted by means of "bee-hive" ovens, which were in the direct line of descent from the primitive piles of the charcoal burner—whose art, it is scarcely necessary to point out, is belied by the traditional title. The so-called charcoal burner makes charcoal, he does not "burn" it, if he knows his business. He piles the twigs left by the woodman into a heap, introduces a sufficient live match, and covers the whole with sods, leaving a vent at the top and a careful provision for limited air admission at the bottom. The pile smoulders and sinks under the weight of the covering, which must be preserved intact, until the whole of the wood is carbonized. The bee-hive coal coking oven is simply this structure in permanence. It deals with 20 tons of coal at a time, which is converted by partial slow combustion into a characteristic hard, grey-coloured, massive coke which is practically pure carbon. The process is a noisome one, and wasteful of the tar, ammonia, naphtha, and other components of the smoke. These are saved by the retort coke-oven, which is a true retort, inasmuch as it is exteriorly heated, usually by the gas from the charge after it has been stripped of its tar and other valuable concomitants. The term coke-oven is retained because the object of the operation is mainly coke, which is made as much like the bee-hive oven product as possible, in order to satisfy the requirements of the blast furnace, for which the more friable product of the ordinary gas retort is unsuitable. Where the market for coke-oven gas is accessible, as in a neighbourhood of coal mines and towns, a portion of the first runnings of the charges is saleable for general consumption as

town's gas; and is so utilized in certain localities. There is now no reason why the whole gas manufacture should not be conducted by the same description of plant, the retort-ovens being fired by producer gas made from the less saleable grades of the coke.

The key to this progressive economy in the treatment of coal by carbonization for the production of town's gas has been stated to be the changed criterion of the quality of the product, from that of the illuminating power of the flame to that of the calorific value of the gas, regarded as a fuel—still capable of showing a light by its simple flame, for the reasons chiefly of public security and private convenience; but far more economically employed otherwise.

CHAPTER VI

MODERN CARBONIZING STANDARDS

THE quality of gas permitted by Acts of Parliament to be supplied in London and a number of other towns which have had recent occasion to seek a revision of the statutory requirement in this respect, may be shortly specified as that which will satisfy a calorimetric test showing that it develops in burning, under standard conditions, a fuel value equal to 500 therms. (for the definition of this term, *see page* 22) per cubic foot.

Parliament has never taken account of the chemical composition of gas, but only of its competency to satisfy a physical test, coupled with a requirement as to purity from certain components of a crude gas which are obnoxious in burning. These are sulphuretted hydrogen and ammonia gases. Not a trace of the former is permitted; and as regards the latter the fact of its possessing commercial value is a sufficient guarantee of its effectual removal from the gas as sold.

As a matter of information, the chemical composition of an average day's gas supply in districts under the modern Parliamentary prescription mentioned, may be as follows:—

		Vols. per cent.
Luminous hydrocarbons . . .	($C_n H_m$)	3·39
Light carburetted hydrogen .	($C H_4$)	25·26
Carbon monoxide . . .	($C O$)	12·82
Hydrogen	(H_2)	40·65
Nitrogen	(N_2)	12·97
Carbon dioxide . . .	($C O_2$)	3·68
Oxygen	(O_2)	1·23
		100·00

The calorific value of the above sample is 493 therms. It would be more but that some of its native naphthas have been extracted. This gas would be made from mixed Durham and Yorkshire coals at the average rate, for coal gas, of about 11,500 cubic feet per ton, *plus* 20 per cent. of blue water gas made from a portion of the coke. Its specific gravity is 0·5 (air = 1·0).

If the composition of the new gas is compared with that of the old (*see page* 14), certain differences appear. The percentage of luminous hydrocarbons is down, as the effect of higher carbonization, elsewhere accountable for the increased production by 1,200 cubic feet of gas per ton of coal. For the same reason the nitrogen is up; and a new component, carbon dioxide, appears, mainly as the effect of the abandonment of lime purification and its replacement by iron oxide. The calculated calorific value of the old gas is 670 therms. per cubic foot.

The old coal gas thus appears on its face to be a considerably more powerful fuel, bulk for bulk, than the present-day mixed product. It is easily proved to be a less economical way of using up the coal, however; for 10,400 cubic feet of 670 therm. gas amounts to a total calorific yield of 6,968,000 therms. per ton, whereas the fuel value of the new product (unwashed for naphtha) equals 7,267,500 therms. per ton of coal carbonized. It is not possible to compare the cost of gas at different dates upon a fair basis; but it is certain that the cost per 1,000 cubic feet of the gas made as in 1890 would be greatly exceeded for similar gas manufactured at the present time. Such gas would also be less suitable for use in the best modern consumer's apparatus; and where it could be burnt, after a fashion, it would prove more wasteful than the modern product.

As an illustration of the chemical audit of the

carbonization process carried on in gasworks, the following tabular statement, prepared by Mr. Alwyne Meade (*Modern Gasworks Practice,* 1916), is instructive :—

Approximate Elements of Coal, Carbonized. (*A. Meade.*)

1 *ton of Coal consisting of*—	
1,792 lbs of *Carbon*—	
Distributed as coke	1,385 lbs.
,, as breeze . . .	107 ,,
,, in gas, as CO_2 and CO .	30 ,,
,, in gas, as hydrocarbons .	130 ,,
,, in tar	122 ,,
,, as retort scurf, cyanide, etc.	18 ,,
123 lbs. of *Hydrogen*—	
Distributed in gas and tar . .	98·5 ,,
,, as ammonia . . .	1·0 ,,
,, as water . . .	18·5 ,,
,, in coke . . .	5 ,,
197 lbs. of *Oxygen*—	
Distributed as CO_2, CO, and combined in	49 ,,
,, tar as water . . .	148 ,,
34 lbs. of *Nitrogen*—	
Distributed in gas (uncombined) .	11·8 ,,
,, in coke	14·1 ,,
,, in tar (combined) . .	1·0 ,,
,, as ammonia . . .	5·8 ,,
,, as cyanogen . . .	1·3 ,,
18 lbs. of *Sulphur*—	
Distributed in gaseous impurities and in liquor . . .	6 ,,
,, in coke. . . .	12 ,,
76 lbs. of *Ash*—	
remaining in coke and breeze . .	76 ,,
2,240 lbs.	2,240 lbs.

It will appear from what has been set down that the chief object of the technicians of the gas industry has ever been the production of the largest quantity of illuminating gas from the coal, and to some extent of the oil, carbonized. The way to this goal is recognized by the term "high carbonization." So imperative is this rule that in the councils of the industry it is a

proverb that "profits are made in the retort house—all besides is mere economy." The bottom requirement to satisfy this condition is adequate heating of the retorts, without which a proper yield of gas from the coal treated is unobtainable. In the fullest sense, however, the expression means a good deal more than stoking. A great mass of detail, administrative, executive, operative, scientific, and technical, goes also to the accomplishment of the desired purpose ; so that it may not be easy to focus helpful criticism in regard to cases of non-success.

Bearing this caution in mind, it remains true that the economical, regular, and sufficient production of illuminating gas is the proper purpose of the gas industry, in the first place. It would be beyond the province of this little book to go deeply into the discussion of what constitutes gas coal, specifically ; but this is to be understood to belong to the great class of bituminous coals, chiefly of the coking type. Consequently, in the process of carbonization, besides the gas numerous valuable residual, or by-products as they are justly called, remain. These are the coke, tar, ammoniacal liquor ; and in the larger works "cyanogen blue" is also recovered. A general statement of carbonizing residuals would be as follows, for a London gasworks :—coke left for sale, per ton of coal—10 cwts. ; tar, 10 galls.; ammoniacal and cyanogen liquor, 30 galls. (10 oz. strength), yielding about 28 lbs. of ammonium sulphate and 2 lbs. of cyanogen blue.

Of these the coke is a direct residual, requiring no special treatment for its recovery. It is usually graded in different sizes for sale. Its fuel value, weight for weight, is equal to that of the original coal. When burnt for steam raising, by hand-firing with forced draught in a "Lancashire" boiler, coke has an evaporation

value of 9 lbs. of water converted into steam "from and at 212° Fahr." It is smokeless, and if only for this reason, coke, or its cheaper small variety, breeze, should be more used for steam raising, especially in town factories. For this purpose it compares favourably in cost with the best steam coal at 5s. per ton higher price. Small coke, briquetted with the addition of pitch, is a valuable form of solid, flaming fuel.

Gas tar is deposited from the crude gas at successive stages of its passage from the retort to the purifying plant. This thick, black fluid deserves to be regarded as the essence, in the fullest sense, of the coal, inasmuch as it shows the greatest variety of composition according to the nature of the coal itself, and of the character of its treatment in carbonization. From the same coal the tar will differ in quantity and composition with the temperature of carbonization. The higher the temperature of extraction, the smaller the quantity, the higher the specific gravity, the larger the proportion of pitch and free carbon and the lower the yield of lighter oil and spirit from the tar. At a carbonizing temperature corresponding to a production of about 11,500 cubic feet of gas per ton, with the old-style layered charges in horizontal or inclined retorts, the specific gravity of the tar was found to be upwards of 1·2 (water = 1·0), and it showed 64 per cent. of pitch, with 20 per cent. of free carbon, and only 20 per cent. of the lighter oils and naphtha. The modern methods of carbonization in full retorts effect a marked improvement of the tar from the distillers' point of view. That is to say, that whereas all coal tar is just tar, if it is to be used for tarring timber, etc., there is an enormous difference in its value from various sources, when required for distillation for the recovery of valuable components.

The following analysis of tar from coke-oven retorts

making gas at the rate of 12,640 cubic feet per ton of a mixture of 50 per cent. South Yorkshire coal and 50 per cent. of Derbyshire coal (Birmingham, 1913), shows that with this style of carbonizing a high yield of gas need not entail the depreciation of the tar :—

PERCENTAGE COMPOSITION OF TAR FROM COKING RETORTS

Light oils, coming over up to 170° C.	24·9
Creosote oils	25·9
Heavy oil	9·3
Above 270° C. (anthracene oil)	11.4
Total pitch	28·0
Free carbon in tar	3·5

These full-retort tars are more limpid than horizontal or inclined-retort tar. They do not contain so much phenol or benzol, in which respect they resemble low-temperature tars ; which in fact they are, as they escape " cracking " in the hot free space of the layered retort. The broad result is that such tars are of greater value as sources of fuel oil ; but are less prolific of benzol and tolŭol. The latter circumstance is what might be deduced from the reputation of the layered charge for producing highly illuminating gas, which is due to the benzol contained in it.

A considerable volume would be required for anything like a full account of the chemical preparations of which coal tar and its immediate derivatives and analogues are the bases. The discovery of the first of the coal-tar dyes by the Englishman, Dr. William Harry Perkin, should have been the first step towards the creation of a great British industry in these invaluable fruits of chemical science ; but the " claim " was " jumped " by the Germans at the period of the creation of the German Empire, when there was an interregnum in their own patent legislation ; and they have practically monopolized the business ever since. Meanwhile it should be known that of all the enormous profit derived

by foreigners from the coal-tar dye and drug manufacture, nothing reached the British gas industry in the shape of an enhanced selling price for tar, which has often been burnt on the works to heat the retorts because it did not pay to send away.

The unfortunate position created for this country, and also for France, by the German monopoly of the manufacture of fine chemicals from coal tar products, was unmasked by the outbreak of the war in 1914, when it was discovered that the enemy command practically the sole supplies of indispensable drugs and disinfectants, as well as plant on the largest scale for turning out high-power explosives and poison gases. It was some months before British gasworks and chemical manufacturers were able to prepare "T.N.T." (trinitrotoluol) from toluene washed out of coal gas and separated from coal tar. Benzol, also, the only native motor spirit substitute for imported petrol, was similarly obtained from purified coal gas. Every ton of coal carbonized can be made to yield about 1½ gallons of "mixed crude spirit," losing a proportionate amount of the illuminating and calorific power of the gas. Strictly speaking, these spirits are not by-products, but normal components of coal gas capable of being extracted if required for a special purpose.

Another valuable by-product of coal-gas making by any and every carbonizing process is ammonia. This is partly deposited from the crude gas, with the condensed water, in the early stages of its travel—*i.e.*, as soon as the temperature falls below 212° Fahr.—and the rest is washed out of the gas by an intentional purification process. The quantity recovered is usually stated in "ounces per gallon." This somewhat cryptic expression refers to the number of ounces of standard

sulphuric acid required to saturate or neutralize the ammonia contained in one gallon of the liquor (*see page* 39, *ante*). It is hardly necessary to emphasize the importance of the recovery of as much as possible of the ammonia afforded by the distillation of coal. Usually in gasworks this by-product is prepared as sulphate of ammonia, one of the most valuable artificial fertilizers. Ammonia is also employed in refrigerating machines.

CHAPTER VII

GASWORKS' PLANT

HAVING in the foregoing pages summarized the nature and results of the carbonization of coal and oil for the production in chief of luminous gas, now established upon an economic fuel basis, we may explain and discuss the practice of gasworks. The most salient aspect of a modern gasworks, with up-to-date equipment, is that of a factory in which a large quantity of heavy and bulky raw material is received, worked up to the last ounce of its commercial value, and from which the manufactured products are distributed continuously as demanded, without a moment's drop or failure to satisfy the requirements of the service.

Gasworks receive their coal by water or by rail, or both; and their oil by tank barges or wagons. The coal carbonized in a year by the London and Suburban gas companies amounts to upwards of four million tons; and in the rest of the gasworks of the United Kingdom probably to not less than twelve million tons more. Therefore the lay-out of industrial works of such magnitude as many of them are, is a matter of considerable importance, proving that the profession of the gas engineer and works manager is one of much responsibility. His tasks are usually made much heavier than mere theory would indicate, by the facts that he invariably inherits many disadvantages and limitations from a past of smaller conceptions, often attended by much dead capital expenditure, whilst his endeavours to modernize his plans and his plant are commonly perplexed by rapid expansion of the business of the undertaking, when they are not rendered

inoperative by the opposite effect of a shifting population. These considerations among others of local significance, go to account for the fact, puzzling to outsiders, of the selling-price of the same quality of gas varying for neighbourhoods of apparently similar character. Where the gasworks happens to have been favourably placed and well laid out in the first instance, perhaps a hundred years ago or thereby—which is rare—and where the capital outlay for the past two or three generations of administrators has been thrifty—which is rarer still—it calls for no exceptional qualities of present-day administration and management of the undertaking to sell gas at a comparatively cheap price, especially if the consumption happens to be growing fast enough to facilitate the adoption of new and improved plant and the scrapping of that which is obsolescent. If, on the other hand, the original works were not only small, but happen to be also badly situated for the supply of coal, and cannot be enlarged, the cost of removal to a new site is likely to prove a heavy burden upon any other than a fast-growing undertaking. In numerous cases also the old error of encouraging competition, invariably ending in fusion of interests, has weighed heavily upon the later business.

Assuming fairly favourable circumstances of situation and a commodious site, or the still more desirable condition of a clear area, the general scheme of a gasworks calls for a "forthright" design, in which the course of every operation lies in one direction, avoiding crossings and turnings-back. This is one of those obvious propositions that are not always carried out. A good deal of vague talk is heard nowadays on the subject of "bulk" production, or energy generation. People who know little of works management indulge in wild suggestions for the establishment of vast

gasworks, or electricity generating stations at the coal-pits' head, or even down in the depths of the mines, whence gas or electricity is to be distributed throughout the whole kingdom. Such proposals ignore two objections which lie upon their threshold. The first is the obligation to acquire or otherwise compensate the proprietors of the existing undertakings, at a cost which would go far towards neutralizing any possible gain by the change; the second is the lack of proof that mere bigness means also economical advantage. Most experience points to the contrary conclusion. The elephant is not so efficient a worker as the horse. The largest works are not often the best managed. Another consideration in point here is that the true economy of distribution is little understood by the "bulk production" enthusiasts. Then there is the question of labour, the difficulty and the hazards of which rise in geometrical ratio with concentration.

In gasworks, concentration and magnification cannot be profitably carried beyond a recognizable limit. Coal must not be stacked too high, for fear of spontaneous ignition. Units of production cannot be of excessive size, or the expenses mount above the savings. When gas mains are too big the cost of valves, etc., and the risks, become oppressive. For many good reasons, therefore, the localization of gasworks in or adjacent to the districts to be supplied is likely to persist as a leading feature of the industry. This aspect of the general question of coal economy in the public service is further discussed in Chapter XIX.

Let us now follow the gas from the retort in which it is made, through the necessary processes of purification to the storage plant. Quickly upon contact with the red-hot surface of the retort, or upon arriving at the hot zone of a vertical retort's contents, a

bituminous coal intumesces, becoming a semi-molten mass, and the first heavy portions of gas come off, together with tarry particles and steam. These pass away through "ascension" pipes, which are liable under some conditions to get choked up with charred, tarry matter. Usually these pipes are led into a closed trough, partly full of liquid in which their ends dip, thus trapping the connection with the retort and preventing a back flow of gas when the retort is opened. Sometimes the liquid seal, to which there are some objections, is replaced by a simple valve. From this point onward, as the temperature of the gassy vapours falls, the deposition of tar and ammoniacal water proceeds, and these fluids are drawn off for storage in tanks. Particular attention to this stage, which is technically termed "condensation" of the gas is necessary to rid the gas not only of the tar and aqueous vapour containing ammonia, but also of a very troublesome concomitant of high carbonization, naphthaline. To this end the course of condensation of the gas, by passing through a series of pipes, wetted outside in summer, if necessary, is ordered until its temperature at the outlet is in the neighbourhood of 62° Fahr. The gas must not be cooled below this temperature at this stage. Unless the naphthaline is got rid of in the condensers, it is likely to go forward in the gas until it gets into the district mains and private services, where it is sure to condense sooner or later in the form of crystals which will block the gasway.

After the condensers it is usual to interpose in the gas stream the relief pump called technically the "exhauster." The purpose of this important machine is to take off from the retorts the back-pressure of gas resulting from the friction of the works' mains, and purifying plant, meter, and gasholder, thus enabling

the actual production of gas to proceed at atmospheric pressure ; which is the best practice. The literal meaning of the word exhauster is not to be insisted upon, since it is no part of the work of the appliance to "exhaust" the charges in the retorts, but simply to counteract the back-pressure, which would otherwise cause loss of gas by driving it out through cracks in the retorts, etc. In many works this back-pressure is considerable. The type of exhauster generally used in this country is a positive rotary pump ; but turbo-exhausters, free running, are also employed for large plants.

The next stage in the treatment of the gas is "scrubbing," or "washing" to free it from the last traces of tar "fog," and to recover the ammonia. For this purpose advantage is taken of the strong affinity of water for ammonia, of which gas it can absorb under ideal conditions 780 times its own volume. In practice, however, the proportion of ammonia present in the gas is so small, not more than 0·6 per cent., that prolonged and intimate contact of the washing water and the gas is requisite to secure the desired effect. Moreover, this washing is also relied upon to assist in removing some sulphuretted hydrogen and carbon dioxide, both of which have affinity for ammonia, with which they combine to form what is called "gas liquor." Owing to the latter phenomenon, it is possible with a sufficiency of ammonia to remove from the gas the whole of its sulphuretted hydrogen and CO_2—the former impurity being the more objectionable. This is called the self-purification of crude gas. Although the theory is sound, practical complications have hitherto prevented its realization on a working scale. For the reason above stated (the poverty of the gas in ammonia) the appliances for dealing with it are somewhat cumbrous or complicated for the actual amount of work they do by way

of ammonia recovery. In works where the cyanogen is recovered from the gas, a special washer for the purpose is interposed here. Several processes for the purpose are practised ; but only in the largest gasworks is the recovery worth while.

After this comes the purification proper, by which the gas is finally prepared for distribution in the state of purity from offensive components according to the statutory requirements. The most obnoxious of these is sulphur, especially in the form of sulphuretted hydrogen. The necessity of removing this impurity, which burns to sulphurous acid and thus gives rise to a choking sensation from the atmosphere receiving the products of combustion of gas containing it, was early recognized in the development of gas lighting. The method of purification followed for many years was by passing the gas through a bed of damp slaked lime ; which is very effectual for the purpose. As already mentioned, incidentally (*see page* 14, *ante*), lime also removed the carbon dioxide. In small country places lime purification is still followed ; but in larger gasworks iron oxide, or an equivalent artificial preparation is used, which recovers the sulphur in marketable form and quantity. It also saves labour, as the "boxes" of purifying material run for a long time by reason of the material being "revivified,"—*i.e.*, restored to its original activity *in situ*—by a regulated admission of a small percentage of air with the foul gas. The effect of this admixture is to continuously oxidize the ferric sulphide formed, which then becomes ferrous sulphide and free sulphur. The air does not go forward as such, but only its nitrogen, which amounts to four-fifths of the bulk admitted.

The removal of sulphuretted hydrogen by either medium is quite perfect, the purified gas containing

no measurable quantity of the impurity—far less than is nominally present in the atmosphere of English towns in winter, due to the free burning of coal in factory furnaces and domestic fires. There remains, however, after the completest absorption of the sulphuretted hydrogen, a minute quantity of sulphur in other forms, the largest proportion being carbon disulphide ($C S_2$). This compound is a product of high carbonization with a layered charge, and may therefore be confidently expected to diminish with the extension of full-retort working. Besides this form, however, coal gas always contains a small fraction of the original sulphur of the coal in forms that have no affinity with any known substance by which they could be removed.

A good deal of exaggerated solicitude has been displayed from time to time in regard to the presence of the remainder sulphur as an impurity in coal gas, and the question was long a happy hunting ground for consulting chemists and engineering experts, whose tussles over the permissible amount of sulphur to be left in the gas after removal of the sulphuretted hydrogen, not infrequently had the effect of swelling the cost of the public service to no substantial advantage. For many years prior to the present century, the gas supplied in London was required by statute to have its content of sulphur compounds other than sulphuretted hydrogen reduced to 22 grains in 100 cubic feet. In point of fact, if the proportion of sulphur were stated wholly in terms of the weight of the same quantity of gas, it would appear as 22 parts in about 24,500, or one in 11,130—which would strike an ordinary person as an infinitesimal quantity. Still, it must be admitted that the sensitiveness of the human mucous membrane to sulphurous and other pungent vapours in the atmosphere is very acute, and the sensation is one to

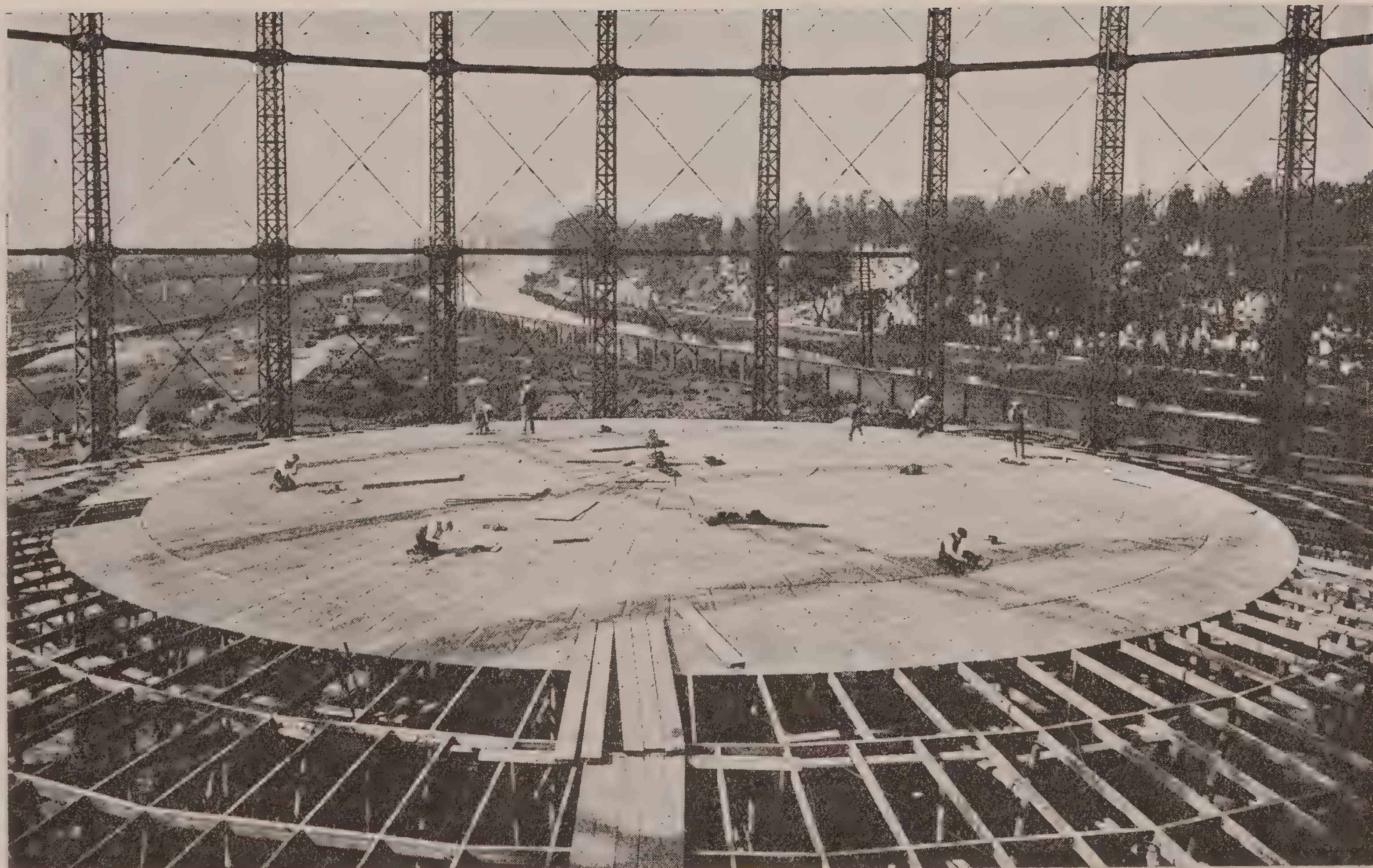

Fig. 10

GASHOLDER UNDER REPAIR SHOWING FIXED SUPPORTS OF CROWN

be spared as far as possible. The point is that so long as coal is burnt in towns the air will be polluted with a perceptible proportion of smoke containing soot, sulphur in its most objectionable form of sulphuretted hydrogen, and tarry particles, and that the worst coal gas is purer than the products of combustion of the best coal. Such sulphur gas as results from the burning of purified coal gas cannot tarnish bright metal, as a winter fog in English towns does very readily. The great extension of the use of gas in London during the present century for purposes previously served by coal fires—steam boiler furnaces on a small scale, household cooking and warming, etc.—has exerted a notably beneficial effect upon the proverbial fogginess of the metropolitan atmosphere.

Returning to the course of gas through the works' plant, after it has passed the purifiers nothing further is needed to fit it for public consumption. Usually the bulk is measured for administrative reasons, by means of station meters, and the gas is then stored in the gasholders, whose towering height dominates their vicinity. These structures consist of a shell of thin iron or steel sheeting with a domed crown ; but no bottom. They rise or fall in a tank of water, which seals the lower edge of the sides, as they are filled or emptied of gas. Notwithstanding their bigness and light construction, they are by no means dangerous in respect of liability to explosion, notwithstanding the ineradicable credulity of newspaper reporters in this regard. The reason for this immunity lies in the fact of the gas being under pressure, so that it merely escapes, with or without subsequent ignition according to circumstances, from any hole made in the gasholder by bullet or bomb. The gas having escaped, the holder simply descends into its tank. If a flaming bomb were to penetrate

into the mass of gas contained in a floating gasholder, it could only ignite the gas at the hole it made ; because gas cannot burn, explosively or otherwise, unless mixed with a large excess of air, or in free contact with the surrounding atmosphere, as in the case of an ordinary burner.

The limits of an explosive mixture of gas and air, mixed before ignition, are from three volumes to ten volumes of air to one volume of gas.

The use of the gasholder is to store the gas as made, and to give it out to the district of supply as required. It therefore compensates between the regular production of the gasworks and the intermittent or irregular demand of the district. Thus a gasholder possesses great economic value, over and above its function in magazinage. Gas loses nothing by storage over water, either in quantity or in quality. The advantage of adequate gasholder capacity, say, equal to a day's heaviest output, is considerable. It enables the works manager to order the production upon the basis of a known mean requirement, irrespective of the maximum demand of the moment, and of its exceptional prolongation over the ordinary period. On the other hand, the gasholder is the most expensive structure in a gasworks, so that any excess of this provision is rare. Of late years the daily and seasonal fluctuations of the output have tended to diminish, and in many large undertakings the erection of new storage has been suspended. Indeed, in some districts the average hourly consumption of gas has become so nearly equalized, that the storage is reduced to what is necessary as a guard against the risk of an accidental breakdown. The structural engineering of gasholders is highly interesting, by reason of the complexity and gravity of the problems involved, and it has therefore attracted and given scope for the ingenuity of many clever designers.

An indispensable accessory of the gasholder is the apparatus called the station governor, which controls the pressure and consequently the quantity of the output of gas into the district. It is the first piece of apparatus pertaining to the department of distribution, as distinguished from the manufacture of gas. Regarded from the point of view of distribution, the gasholder is the feeder of the trunk and district main system. It sends out the gas automatically, by the force of gravitation represented by its falling weight, which gives the necessary pressure to the gas output.

CHAPTER VIII

GAS TRANSMISSION AND DISTRIBUTION

THE pressure is the motive force that sends the gas through the main system, right up to every particular outlet from which it is expected to effect its purpose of serving as the wherewithal of lighting, heating, or the generation of mechanical power. The two elements of a good supply of gas, *pressure* and *quantity*, are both essential to the purpose. If the pressure is insufficient, no amount of main capacity or size of consuming appliance will operate satisfactorily, whilst unless the capacity in point is adequate the pressure will drop when the tap is opened.

Gas pressure is commonly measured in terms of the vertical height of a column of water which counterbalances it, usually expressed in inches and tenths of an inch. The diagram at the end of this chapter explains the source of gravitational pressure. Here the gasholder is seen floating in its tank upon the contained gas, by its dead weight displacing the inside water-line, which remains at a lower level than that outside which is under the atmospheric pressure. The difference, multiplied by the area, is the measure of the water which is equal in weight to the floating holder. Assume the diameter of the holder to be 100 feet, and its weight 100 tons. It therefore covers and encloses a horizontal circular layer of water of this diameter—how high ? A ton of water has about 36 cubic feet of bulk, and since the superincumbent weight is 100 tons, there are 3,600 cubic feet of water displaced within a circular area of 100 feet diameter, which is 7,854 square feet super.

Dividing the cubical measurement of the displaced water by this figure, we get the third dimension, the vertical height in question :—

$$\frac{3{,}600}{7{,}854} = 0{\cdot}458 \text{ ft.} = 5 \text{ inches and } 5 \text{ tenths.}$$

nearly, which the practical gasman would call "55 tenths," *for the gauge, or standing gas pressure thrown by this holder.*

This pressure, be it observed, is pressure over and above that of the atmosphere for the time being ; which means that it is a force tending to press the gas outwards from the containing vessels, holder or pipes, and therefore prevents the air from getting in. This condition must always exist in a gas distributing system, as the *sine quâ non* of public security ; for, as already observed, so long as there is no admixture of air with the enclosed gas it cannot explode. If there were no draught upon the mains, through the opening of a discharging orifice somewhere in the system, the standing or *static* pressure of gas would be and remain everywhere the same, and equal that of the gasholder upon the water in its tank. The condition would be that of pneumatic equilibrium, with nothing to disturb the balance.

The moment a tap is opened anywhere in the system, gas is expelled by the falling weight of the holder, it may be miles away. The pressure operating the flow now becomes *kinetic* energy, which has to be maintained or it will sooner or later be expended—as a weight-driven clock "runs down." It is the same with gas distribution : the kinetic, or working pressure, is maintained by pumping gas into the holder to keep it afloat. Moreover, it is important to bear in mind that this working pressure at any point of the distributing system is less than that

of the gasholder, by reason of the friction loss sustained by the gas in the course of its travel through the trunk mains, district mains, service pipes, consumer's meter, the internal pipe connections, and the burner orifice.[1] It is very necessary to have a correct understanding of these truths, more especially as the fact of gas being lighter than air, and therefore rising in the atmosphere apparently by its own volition, obscures the operation of the physical laws applying to this as well as to more tangible kinds of matter. Gas has both weight and substance. A common gas fire, for example, consumes gas at the rate of, say, 33 cubic feet per hour. The gas will probably have a specific gravity of 0·5, air being 1·0. That is to say, it is half as heavy, bulk for bulk, as air at equal temperature and pressure. At 32° Fahr. and normal atmospheric pressure, air weighs 0·0807 lb. per cubic foot. Halving this for the weight of the gas, and multiplying by 33, we have $0{\cdot}04035 \times 33 = 1{\cdot}33$ lbs. of fuel in the gaseous form to bring hourly to the point of combustion, possibly from a distance of some miles. Every inch of the way, this gas is obstructed in its passage. It rubs against the sides of pipes, probably rusty, corroded, with a varying depth of water lying in the bottom, with innumerable sharp corners to turn, and has to negotiate constricted connections at the meter, actuate this machine, and finally escape at a small nipple, after which it has to do work upon the surrounding air in inducing this inert gaseous matter to accompany it in sufficient quantity to support its combustion. Only the kinetic energy corresponding to the maintainable gauge pressure enables this work to be performed by the gas. Consequently, it is the duty of the

[1] See diagram on page 61 showing the origin of gas pressure in the mains.

gas distributing engineer to see that the pressure-drop is never so much as to reduce the maintained pressure at the point of combustion below the figure for which the appliance for the purpose—illuminating burner, fire, cooker, or gas engine—is designed. Should this happen, the consumer will probably complain of "bad gas."

The apparatus upon which the distributing engineer depends for regulating the district pressure is the governor—assuming the sufficiency of the gasholder pressure behind it. We have instanced a static pressure of 55 tenths, which would be enough in the majority of cases of distribution over a small to medium-sized area of supply; but is considerably exceeded in large undertakings. The gasholder pressures, in the first place, are not uniform. Most holders are "telescopic," consisting of several "lifts" connected by hydraulic seals, and giving cumulative pressures which have to be unified by the governor. This apparatus is itself a small model of a gasholder, whose "bell" carries a parabolic conical valve in the mouth of the outlet main, and is so counterbalanced that whilst a rise of pressure on the inlet side due to the coming into action of a heavier gasholder raises the bell of the governor and so tends to reduce the opening left by the valve, the same effect is produced by any "backing up" of pressure on the outlet side due to decreased draught on the district. The setting of the height of the bell, and consequently the extent of the gas-way opening by the valve, is effected by putting on or taking off weights on the top. Thus the amount of the discharge of gas can be adjusted with relation to the pressure available or desired. This is where the voluntary act of control comes into play, which cannot be dispensed with by a completely automatic arrangement, because

a degree of intelligent prevision is called for, it may be to husband the supply at a pinch, or to anticipate a suddenly increased demand in the district consequent upon fog, snow, or other cause of hurried lighting up.

The question of the amount of pressure necessary for the satisfactory supply of any district is only to be answered by observation and local experience. Originally, and throughout the period of gas supply for lighting only by the luminous flame, district pressures were not required to exceed the low standard imposed by this class of burner, which was not more than six or seven tenths. At higher pressure the flames simply roared, so that careful consumers got into the habit of checking the supply at the meter ; hence there was nothing gained, but a good deal to lose through leakage by keeping up a high main pressure.

With the coming of the Welsbach burner for lighting, and a settled policy of encouraging the use of gas for cooking by the hiring-out of the apparatus, a new order of district pressures became necessary. The incandescent burner and the boiling burner alike belonged to the Bunsen type, in which a certain proportion of air is mixed with the gas before ignition ; and for the proper functioning of these burners a pressure at the point of ignition of not less than 16 to 20 tenths is requisite. Present practice in gas distribution is based upon this rule.

The ideal town's gas supply would have a constant pressure at all points of 30 tenths, or three inches of water column ; and the district pressure would be instantly controllable everywhere from the distributing centre. Unfortunately there is scarcely a gas consuming area in the kingdom in which this condition is realizable, chiefly by reason of the impaired heritage from a less enlightened past. Like the manufacturing

plant, some section of the distributing system is constantly falling short of the increasing requirements of the present day, or exists under disabling circumstances almost defying amendment. Trunk mains laid under congested thoroughfares thirty years ago cannot be pulled up to the blockage of traffic, while being daily overloaded with the supply of new districts beyond. Such disadvantages can sometimes be remedied by the introduction of power "boosters" of the gas pressure. Extensive dispositions of this character are becoming common, not only in congested town areas, but also for the supply at high pressure of factories and populous places remote from the gasworks. This is quite a new chapter in the technical record of gas distribution, from which much satisfactory business is expected to accrue. Coal gas of the normal quality bears compression and high pressure transmission without appreciable loss of value.

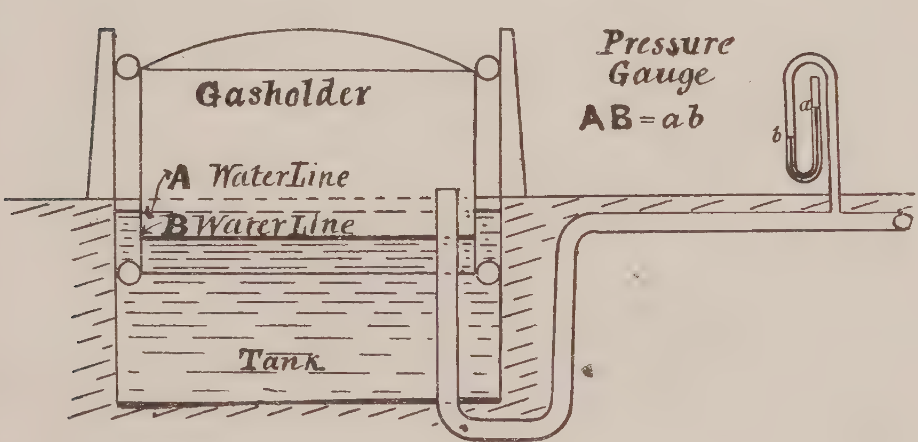

FIG. 11

DIAGRAM SHOWING ORIGIN OF GAS PRESSURE IN THE MAINS

CHAPTER IX

GAS TRANSMISSION AND DISTRIBUTION—*continued*

THE main pipes commonly used for conveying gas to and through towns are of cast iron, and run up to 48 inches diameter. The smallest now laid underground are 4 inches diameter. They are cast in 12 ft. and 9 ft. lengths, with socket, or turned and bored joints. The former joints are caulked with yarn and run with lead, the latter are painted and rammed together. No gas main should be laid in a roadway at a less depth than 2 ft. 6 in. from surface to top ; but in populous streets it is usual for the supply mains to be laid under the side-walks, in order to minimize excavation for house service pipe connections. It is not necessary to lay such mains so deep. In certain cases the mains are accommodated in subways, which obviates excavation altogether ; but the practice has no other recommendation, whilst greatly increasing the first cost. Modern high-pressure main practice favours steel piping, which can be put together on the surface in long lengths and dropped into the trench, with considerable saving of time and cost.

A mass of legality has accumulated round gas mains. In the beginnings of the gas industry, the need for making use of the subsoil of the public highways for the distributing mains brought the undertakers up against the common law of nuisance, it being an indictable offence to cause any obstruction of the road surface for private ends, irrespective of proved damage or annoyance. Right of action lay with the highway authority. Consequently a special Act of Parliament was necessary to give gas supply undertakers the right to use

the subsoil of the King's highways for their business purposes, in respect of laying pipes, and opening the ground afterwards for inspection, alteration, repair, making connections or removal. Of course, the exercise of this right had to be hedged about with conditions framed in the public interest, and also for the protection of other users of the available accommodation. Only in a very small number of instances is payment exacted for this use of the roads, which are common property without particular ownership. The highway authorities only exercise guardianship over the actual surface ; and even this has to be regulated with due regard for the owners of property buried underneath.

Incidentally, it was this matter of road-breaking which demonstrated the undesirability of competition in gas supply, since in parts of London, where at one time two or three gas companies were carrying on in the same street, the incessant interference with the traffic by road openings became intolerable. Thirteen London companies were first districted, and eventually reduced to three by amalgamation.

Closely connected with the general subject of gas distribution by a pipe system, is the little-understood question of "unaccounted-for gas," which has occasionally been magnified into a bogy of the town. It has an unquestioned foundation of fact in accidental and unpreventable leakage. Now and again the public mind is disturbed and distressed, by painful fatalities occurring in town habitations, directly traceable to a leak of gas from a street main, perhaps without the existence of a gas connection on the premises. Professional press practitioners of the art of "making the public's flesh creep," have used these deplorable accidents as a text for dilating at length upon the danger of the millions of cubic feet of lost gas, which the

published accounts of the gas companies show must be lingering about the hollow places under the street pavements, ready to poison His Majesty's lieges, or to blow up their homes. The truth being, that only in rare circumstances is it possible for gas to accumulate dangerously in any place not constructed for the purpose. Still, there is the possibility, and therefore in modern town management care is taken to avoid making or leaving unventilated voids under road and foot pavements. In despite of all precautions, subsidences do occur which result in partings between the subsoil and the crown of roads and sidewalks, and by the same agency gas pipes are broken and their contents disseminated through the empty spaces, with the confined air, eventually percolating into the basements of frontages.

The sense of smell is the most efficient protection against danger from all leakages of gas, whether from outside or indoors, consequent upon broken pipes or gas taps inadvertently left open. It is quite easy to detect a strong smell of gas when it is present in the almost infinitesimal proportion of one part in 10,000 of air—far below the minimum of a poisonous or an explosive mixture. In view, however, of the numerous odours usually arising from the traffic of the streets, or the drains, the instrumental testing of lines of gas mains for leakages is effected by means of a portable apparatus. This instrument (Ansell's Indicator) depends upon the physical phenomenon of the transfusion of gases of different specific gravities through a separating porous diaphragm, and by the movement of a pointer it quickly shows the rise of pressure thus caused.

In districts of average subsoil stability—that is, where subsidences caused by pumping water, or mining operations are not in evidence—the actual gas leakage,

including that due to known pipe breakages, work upon the mains and service pipes, etc., will seldom average more than 1 per cent. of the total bulk transmitted. A further apparent loss is purely a matter of account, being represented by difference between the real volume of the output and the volume registered as sold by consumers' meters (*see page* 68): To which is added any excess of consumption by the public street lamps, which are not metered, but are supplied by contract based upon estimated consumption; together with the effects on volume of condensation of the water vapour carried off by the gas from the gasholder tanks, and the shrinkage of volume of the gas itself due to cooling in the subsoil of the roads.

The delivering capacity of gas mains is theoretically ascertained by calculation according to a mathematical formula, of which there are several given in the engineering text-books, which also contain worked out tables for convenient reference. The formula in general use by gas engineers is that of Dr. Pole:—

$$Q = 1{,}350\, d^2 \sqrt{\frac{p\,d}{s\,l}}$$

Where Q = quantity of gas delivered, in cubic feet per hour.
l = length of pipe in yards.
d = diameter of pipe in inches.
p = pressure drop in inches of water.
s = specific gravity of gas (air = 1.)

The term "pressure drop" means the frictional loss of pressure or "head" from one end of the pipe to the other—that is to say, it is the difference between the inlet and the discharge pressures. Dr. Pole's formula was composed sixty years ago, and although substantially correct for pipes of the comparatively modest sizes of the period, from 6 in. to 9 in. diameter, and for the low pressures then employed, which did not sensibly affect the density of the gas, its results

need intelligent adjustment to the larger pipes, and especially to the high-pressure transmissions of the present.

A slide-rule has been issued by the Keith-Blackman Engineering Company, London, for solving all forms of the Pole formula at a glance. The following examples illustrate practical bearings of the problem :—

Question.—What diameter of main pipe will be required to deliver 10,000 cubic feet of gas per hour at a distance of 1,000 yards from an adequate source of supply, with an end pressure of not less than three inches of water? The pressure at the source is five inches.

Answer.—For a pressure drop of two inches, as stated, assuming the specific gravity of the gas to be 0·5, the nearest size of pipe is 7 in. diameter—say, 8 in., to make sure.

Here a further query of practical engineering comes in: If the supply were for the feeding of gas engines, it would be good judgment to decide upon the 8 in. main, because of the large quantity of cushioning gas that would be available on starting up, or in the event of a small irregularity of the pressure. On the other hand, in the case of the supply of industrial furnaces, or lights, the cost of the large main might be economized by a smaller pipe with a "booster." Working up to 100 inches of water, or about 7 inches of mercury ($3\frac{1}{2}$ lbs. per square inch), a 3 in. pipe would suffice.

The supply of gas to public lamps has been mentioned; and this is a convenient stage for dealing with this practice, which is one of the primary obligations of statutory gas undertakings. Often, in the case of foreign undertakings based upon the concession system, the public street lighting is the *raison d'être* of the venture. In the United Kingdom, the opposite condition

prevails, as regards the revenues of the gas undertakings, which commonly view with equanimity—save for the sake of the advertisement—the loss of this branch of business to a municipal electric lighting department.

Ordinarily the local authority obtains the statutory right to a supply of gas for the public street lamps at the lowest price charged to any private consumer in the district ; the provision of lamp-posts, lanterns, burners, etc., and their maintenance being a charge upon the local lighting rate. By the Gasworks Clauses Act, 1871, Clause 24, the undertakers are compelled to supply gas to any public lamps within the distance of fifty yards from their mains. The spacing of the lamps is optional, and is usually determined by the character of the locality. It is necessary to remember that the police and wayfaring lighting of roads, highways and byways, alleys, courts, wynds, etc., is not a question of illumination, like the lighting of a work-bench or a reading desk. It is more akin to the beacon lighting of a waterway, being intended to facilitate traffic. Hence in suburban districts single incandescent lamps of 80 to 100 candle-power, kept clean and in good order, and not more than 80 yards apart, is good lighting. As the thoroughfare approaches the busy streets, simply closing up the lamps gradually converts the "beacon" lighting into veritable roadway and foot-path illumination. For the widest and busiest streets, market-places, railway station approaches, and promenade lighting generally, high-power gas lamps of from 1,000 to 3,000 candle-power are available.

The duration of public lighting periods is a matter of latitude, and also in some degree of public ways and customs. Thus a very great variety has been introduced into the practice of different localities. Whereas in rural parts the public lamps may not be

lighted at all in the summer, in town a full schedule approximating to 4,000 hours per annum is in force. Only a certain number of lamps may remain alight all night, others being reduced or extinguished at some time of the evening. A vast amount of ingenuity has been expended on the solution of the problem of lighting and extinguishing public street lamps automatically or mechanically, with such a measure of success that some of the devices in use will do everything except tell the distant watcher in the gasworks' governor room when anything goes wrong. Hence a certain amount of surveillance is still necessary ; but the economy and convenience of a good mechanical street lamp-lighting system is something considerable.

The ordinary system of supplying gas to private consumers is by meter, which was first legalized by the Sale of Gas Act, 1859. This Act made the only legal standard, or unit of measure, for the sale of gas by meter, the cubic foot containing 62·321 lbs. weight of distilled or rain water, weighed in air at the temperature of 62° Fahr., and barometer 30 inches. Under these conditions an Imperial gallon of water weighs 10 lbs., and a litre 2·2046 lbs. Local authorities were required to provide themselves with models of the cubic foot bottle, and of the gasholders used in the actual testing of consumers' meters, and to appoint inspectors under the Act. Meters were to measure within a margin of error of 2 per cent. in favour of the seller, or 3 per cent. in favour of the consumer. Thus "the turn of the scale" is on the average on the side of the purchaser of gas, who, if dissatisfied with the indication of his meter, can always claim to have it tested. The meter is only a *primâ facie* witness of the quantity of gas passed through it, not conclusive proof.

CHAPTER X

GAS MEASUREMENT AND REGULATION

THE metering of gas, meaning its measurement whilst flowing, without interruption, is effected by at least four different kinds of instruments, whereof only two are recognized as legal, namely, "wet" and "dry" meters. The others—rotary and Venturi tube systems—are useful for works' purposes; but being inferential in operation are not stamped. The wet meter is the most accurate measurer of flowing gas, and is the kind employed in gasworks to ascertain the quantity made, and also in all analytical apparatus calling for precise gas measurement. It was for many years the only consumers' meter, and is still so used in many localities. It consists of a chambered drum, revolving horizontally on an axle which carries a worm-wheel at one extremity, gearing with a wheel upon a vertical spindle which communicates motion to the wheel-train of the registering index. The drum chambers are sealed in water, and are so disposed that one chamber is always open to receive the gas, which flows from the inlet pipe; and as the chamber fills it rises out of the water and so causes the whole drum to revolve. So long as the water-level remains constant, the measurement must be accurate. This condition, however, needs watching, as the gas usually absorbs moisture from the wetted drum. Consequently, when left on the consumers' premises, wet meters require periodical watering, and the water is liable to freeze and so stop the passage of gas during severe weather. In cold climates this difficulty is overcome by filling the meter with a non-freezing fluid, such as calcium chloride.

In London and numerous other districts, the "dry" meter has supplanted the older form, for the sake of its greater convenience. It is equally reliable in practice. As shown by the drawing, it consists essentially of two circular bellows, whereof one end is movable horizontally, whilst the opposite end is the fixed vertical partition between the two vessels. The extent of in-and-out travel of the movable ends is the element of measurement. The bellows and their lever attachments are enclosed in a rectangular case, the upper part of which contains the registering wheel train and index. The gas is admitted first inside the case and outside the bellows, so that in the event of a leaky case it is always unmeasured gas that escapes. As the pressure of the inflowing gas pushes in the end of one gas bag, expelling the gas previously contained in it (which goes to the burners) a crank tends to close this gas-way against itself, and to open another by means of slide valves similar to the steam valves on an engine. The movement goes on continuously, and the travel of the bellows-ends drives the registering train. The figures shown on the visible index are multiples of cubic feet.

A variety of meter that has come into great prominence of late years is the "prepayment" or "slot" meter, which has proved an enormous boon to many who for any reason were previously debarred from obtaining a supply of gas on the ordinary system. The prepayment attachment consists of a means of determining the quantity of gas allowed to pass through the meter in relation to the value and number of coins inserted in the place provided, and subsequently held in a money-box "until called for."

Several methods of effecting the purpose are in successful operation. Indeed, the popularity of the system

has been a cause of embarrassment to many gas undertakings, owing to the large outlay of capital required, and the smallness of the return, as many of these meters (which cost more than those of the ordinary type) brought in a very few shillings of gas rental. The difficulties of theft from and maltreatment of the meters were at first rather forbidding; but the public benefit accruing from the suppression in towns of the dangerous petroleum oil lamp is a gain worth the pains of securing by this device. It should be borne in mind that the coin-actuated attachment is no part of the measuring gear, and its correctness is not vouched for. The charge is made out on the ordinary registration of the meter, any discrepancy with the contents of the money box being made good at the periodical collection.

The sizes of consumers' meters are given as the number of " lights " they are designed to supply, the " light " being taken to consume six cubic feet of gas per hour. In practice meters will bear a considerable overload, although this accommodation must not be pressed too far, as the machine, which bears a strong resemblance to a steam engine, has a limited life. Usually, meters are hired out by the undertakers, at a rental calculated on their cost. Consumers are at liberty to provide their own, which, of course, must likewise be officially stamped.

Where gas is distributed at a higher pressure than is necessary for the service of the appliances for its consumption, it is expedient that the excess should be corrected by the interposition, before the meter, of a suitable consumers' governor. Such governors are of two kinds, for controlling pressure or quantity respectively. As the name implies, the latter form can be set to pass a determined volume of gas per hour, at any inlet pressure above the minimum at which the

control becomes operative. Thus they are suitable for limiting the consumption, say, of a gas fire, a public street lamp, or any single appliance the consumption of which is to be restricted to a certain maximum. The pressure governor can be set to pass gas at a certain maximum pressure, irrespective both of inlet pressure in excess of the minimum and also of the quantity of gas passed at the set pressure. Therefore it will control the pressure and consequently the consumption of a number of burners at the same altitude. The gas office should be consulted on this matter of governing pressures on consumers' premises.

The pressure under which gas is delivered through pipes, or through an opening into the atmosphere (as from the nipple of a burner) determines the velocity of discharge, and this in conjunction with the size of the opening determines the quantity delivered in a given time. The rule for the discharge of gas from an orifice, under constant pressure both of the gas and of the atmosphere is :—

"The rate of delivery varies directly as the square root of the pressure head."

Example.—A gas burner consumes at the rate of ten cubic feet per hour under a pressure of two inches of water. What will be its rate of consumption if the pressure is increased to eight inches ?

Answer.—The consumption will be doubled, because the square roots of 2 and 8 are respectively 1·414 and 2·818.

In everyday practice such large differences are exceptional, and it is customary to assume as a safe working guide, that doubling the pressure will increase a consumption by one-half. Referring to the previous remark, implying that relative altitude affects the problem, it must be borne in mind that the effect of

height is to reduce the atmospheric pressure. In practice it is customary to assume that for every additional altitude of 12 ft. vertical, the pressure of a gas distributing system rising from a lower level is increased by one-tenth of an inch of water. Barometric changes of atmospheric pressure at a uniform level above the sea do not affect gas discharge, because the reduced resistance of the air to the flow of gas from the burner is exactly balanced by the reduced pressure of the air upon the gasholder.

It is to be understood generally, that the maintenance of the proper working pressure is eminently desirable in regard to the satisfactory functioning of all gas-consuming appliances. If the pressure is right, it means that the whole system of supply is also right. Even irregularities of the fuel value of the gas itself lose much of their harmful effect under the same favourable working condition.

CHAPTER XI

GENERAL USES OF GAS

REFERRING now to the particulars of the composition and other qualities of a gas supply touched upon in the course of the discussion in previous paragraphs of the results of coal and oil carbonization, it is possible to study the same data and follow their bearings upon and in connection with the ordinary uses of gas by the consumer. Originally the sole purpose for which anybody bought gas was to have a means of producing artificial light, which it accomplished in one way—by the burning of a luminous flame. Hence the limitations of the manufacture already recounted. As a matter of historical fact, the fuel aspect of the same gas was even then to some extent exploited as a side-line, in England at any rate. Abroad it was too costly. About the year 1880, attention was attracted to the possibility of employing gas as a source of motive power by the introduction of the first practical gas engine, the invention of Otto and Langen. This was a motor of a semi-atmospheric type, consisting of a vertical cylinder in which a flying piston was projected upwards by the explosion of a charge of gas and air, to be returned by atmospheric pressure when the products of the explosive combustion were exhausted. A rod attached to the piston had a rack formed on one side, which on the downward stroke engaged in a pinion wheel on a cross-shaft, and thus caused revolution. Noisy and extravagant of gas as this machine was, in the absence at the period of anything equally convenient as a small prime mover it had a certain vogue. About the same period tentatives in the direction of the employment of gas for

cooking, and heating interiors by close stoves appeared. Influential leaders of the industry perceived, in the experimental success of these fuel applications of gas, the promise of such an increased use of gas by the public as would tend to lower its production cost, which would again react upon the new movement. Consequently, an impetus was given to the gas-cooker enterprise by the adoption on the part of the gas companies of the policy of hiring-out approved apparatus of the kind ; which encouraged the design and manufacture of substantially made and efficient goods—a development, be it said, which is still in progress. Meanwhile, a real gas engine on the principle of internal combustion was brought out by Dr. Otto, a German, who gave practical embodiment to plans formulated but never worked out by a Frenchman, Beau de Rochas. This is the parentage of the motor industry of the present day, all petrol and oil engines being gas engines, and, in the language of science, heat engines.

As already observed, the ultimate dethronement of luminous flame illuminating power from its dominant place in the gas industry was the direct consequence of the invention by Ritter von Welsbach, in 1885, of the means of obtaining more light from gas by applying its heat to raise to a temperature of high incandescence certain refractory substances previously almost unknown to science, and quite without industrial value. Many years were to elapse, and much work had to be done in a variety of fields, some apparently remote from the matter at issue, before the logical outcome of all these influences was authoritatively recognized, and flame illuminating power ceased to be the criterion of value of town's gas.

It is possible to admit, in the light of the new knowledge, that flame luminosity itself is a phenomenon

attributable to heat. The commonly accepted theory of the phenomenon is that it is caused by the combustion with atmospheric oxygen of a crowd of carbon particles liberated by the heat of the flame itself. The thicker these particles, the brighter the flame, up to a point. Also, the hotter the flame, the brighter the incandescence of the carbon particles. Thrust a cold body into such a flame, it becomes covered with extinguished carbon—soot, in short—which if left alone would have burnt out smokelessly. There is no artificial combustion hotter than that of the skin of flame where the carbon is burning upon contact with the surrounding air. Platinum melts there. This fact is interesting, but of small practical moment, because it is useless for fuel purposes. This skin, or zone of high-flame heat, is very thin, and its constitution is easily upset. Very small flames have but little of it ; and big flames readily lose it, and smoke. The important truth of the matter, in regard to gas of the kind now in question is, that the total amount of heat produced by the combustion of a unit volume of it is always the same, for the same gas. The intensity of the light emitted by its flame may, and indeed does, vary greatly according to the manner of burning it ; but its calorific value is invariable. The degree of intensity of its combustion can be so varied as to yield wide differences of the temperature of the operation, but that is the extent of its amenability to treatment.

It is important to recognize that the purchaser of gas for the purpose of illumination only is not injured by the abandonment of the method of appraising it by the luminous flame, if he will but march with the times and use the new gas in the new and more economical way. Rather is he greatly in pocket, for instead of having to consume gas costing, say,

4s. per 1,000 cubic feet at the rate of 5 cubic feet per hour, in the careful laboratory fashion (which he never followed), or at the rate of 8 or 10 cubic feet per hour, which was usual with the common flat flame burners of the period, he can by the new method of incandescent lighting get either 100 candle-power of illumination for 5 cubic feet of gas probably 25 to 30 per cent. cheaper—or get his old standard of illumination at a tithe of the cost. Most people, as a matter of course, take their advantage in the shape of more light, as the different appearance after dark of English towns within the present century amply demonstrates.

This is not to say that the British gas industry is yet prepared to drop all luminosity from its staple product. Whilst the incandescent gas light is cheap and brilliant to a degree, it is dependent upon the pressure of a foreign and supplementary substance, and also upon the integrity of certain adjustments of apparatus, easily destroyed by a blow. The self-luminous flame of town's gas, on the other hand, is entitled to rank as the safety light of civilization. In dormitory corridors, in railway tunnels, at theatre exits, in stable-yards—everywhere, in brief, where a light must be shown under all conditions without fail, there is no proper substitute for plain gas, which needs no attention and burns year in and year out against a time of need.

The question of flat-flame candle-power, however, is of small importance, and the figure must be governed by the call for a cheap fuel gas of the quality already mentioned—about 500 therms.—which shows a luminosity in the neighbourhood of one candle per cubic foot of hourly consumption. Flame luminosity is shown by such gas down to a calorific power of 400–425 therms., below which the flame, although itself visible, gives

no serviceable illumination. This consideration may therefore be regarded as setting the lower limit to the calorific value of a town's gas supply, the upper limit referring to the cost of manufacture and the requirement for extracing from a richer gas the benzene, which is of greater utility for other purposes than burning in this connection.

The proposition which the contemporaneous practice of the British gas industry requires to be established is, that a product of the quality herein approved as the standard best adapted to satisfy all-round purposes and at the same time well suited to the existing regime of the industry—namely, gas of 500 therms. calorific value—with a margin of say, 5 per cent. over or 10 per cent. under this mean—is an economical basis for the industry generally.

CHAPTER XII

GAS AS FUEL

It has been shown (*see page* 38, *ante*), that on the basis of thermal value obtained from the coal carbonized, a gas of 500 therms. grade is more economical of coal than a richer gas made to satisfy the obsolete 16 candle-power illumination standard. Let us see how the comparison of calorific powers of the two gases works out in practical use.

The calorific measure of a fuel can be ascertained in two ways—by direct experiment with an apparatus called a calorimeter ; or by calculation of the same from its approximate chemical composition, in which the combustibles are taken at values originally obtained by experiment with their pure elements. These methods should agree fairly well ; and obviously the latter is the only one available in the absence of a trustworthy instrument for direct determination. Good gaseous fuel calorimeters are of recent date, whereas the accepted calorific valuations of the principal elements of fuel are classical. Applying the method of calculation to the example of old gas on page 14, we have :—

Combustibles.	Vols. per cent.	Calorific value, therms.	Air required for complete combustion.	Vols. per cu. ft.
Luminous hydrocarbons . .	5·40	124·2	115·6	
Light carburetted hydrogen	37·90	375·8	360·0	
Carbon monoxide . . .	7·40	25·3	17·7	
Hydrogen	46·44	147·7	111·3	
		673·0	604·6 =	6·04

In the sample of 500 therm. gas given on page 38, we have :—

Combustibles.	Vols. per cent.	Calorific value, therms.	Air required for complete combustion.	Vols. per cu. ft.
Luminous hydrocarbons .	3·39	78·00	72·54	
Light carburetted hydrogen	25·26	250·45	239·97	
Carbon monoxide . .	12·82	43·77	30·77	
Hydrogen . . .	40·65	128·95	97·56	
		501·27	440.84	= 4·4

Thus the comparative total calorific value of these two samples of gas is as 673 to 501—*e.g.*, the old gas is apparently nearly 34 per cent. more powerful than the new. It could not now be made at an equivalent difference in cost, however, having regard to the enhanced prices of all materials and labour, even if the necessary materials were procurable in the requisite quantity, which is impossible. Moreover, probably 1·5 per cent. of benzene vapour formed part of the luminous hydrocarbons in this sample, which would account for 56 therms. and if extracted (as in the case of the 500 therm. gas), the calorific superiority would be correspondingly reduced.

Apart altogether from the superior economy of raw material credited to the latter, its comparative cheapness is a very strong recommendation, for the reason that in the general use of any fuel, more than half of its total calorific value is lost. Therefore, the corresponding loss of money by the purchaser is less with the cheaper than with the more expensive article. He can better afford the unavoidable waste due to imperfect appliances, unskilled handling and sheer carelessness. This consideration applies with particular force to the use of a constant supply, like that of gas or water, which calls for deliberate action in turning off the tap. Obviously where a fire has to be kept up by the labour of carrying coal, and attention to the combustion—cleaning the grate, and so on,—the consequence of

heedlessness is the dying down and ultimate extinction of the fire, whereas with a gas supply it is the exact opposite.

Before the recent stringency came about in respect to the supplies of the prime quality raw materials handled by British gas manufacturers in the last century, a lower grade of gas ruled in Continental cities; which circumstance, coupled with the higher prices, made easier the way to the adoption of the incandescent method of lighting. In Germany especially, it was soon recognized that an illuminating power standard was an obstacle to the realization of the full economy possible with the new system of lighting, calorimetric tests proving that a highly carburetted sample of gas was absolutely less effective in the Welsbach mantle burner than a corresponding sample from which the benzene enrichment had been extracted. Assuming the practical utility of the Welsbach light, this observation settled the issue, the result being further facilitated by the circumstance of there being no German master-patent for the Welsbach invention, as in the United Kingdom and elsewhere.

The natural inquiry suggested in this connection is:—"How is it that a gas of 600 therms. calorific value can be ranked as no better for a fuel application than a gas of 500 therms. value?"

The answer is to be found in another element of the practical characteristics of a gaseous fuel, namely, the *intensity* of its combustion; which is distinct from the calorific value. In the analyses of gas given on pages 79–80, *ante*, appears a third column giving the quantity of air required per unit of volume, for the complete combustion of the gas. It is shown that the old style 673 therm. gas needs per cubic foot, by calculation, 6·04 cubic feet of air; whereas the 500 therm.

gas requires only 4·4 cubic feet of air per cubic foot of its volume.

Now, in the act of burning all this air and the unit volume of the gas combine to determine the energy of the process. If, therefore, as a Frenchman, Deschamps, pointed out, we regard the calorific value of the unit of gas as spread over and through the total volume of the gas and its " comburant," air, we shall have an indication of the intensity of the combustion—thus :—

$$\frac{\text{Calorific value}}{\text{Vol. of gas} + \text{vols. of air}} = \text{Calorific intensity per vol. of combustion products.}$$

Here (1) :—

$$\frac{673}{1 + 6{\cdot}04} = 95{\cdot}5 \text{ therms.}$$

and (2) :—

$$\frac{501}{1 + 4{\cdot}4} = 92{\cdot}8 \text{ therms.}$$

The small difference would be more than compensated for by the better commixture of the smaller bulk of air with the gas, than could be achieved in the same period of time (or length of mixing tube) in the case of the larger bulk. The latter observation is of great practical moment. A Welsbach burner tube is of a certain size, and will therefore pass a fixed volume of gas at a certain velocity, in unit time. The more air there is in the fuel mixture the less combustible passes, and the amount of work done falls off accordingly. These considerations go to explain why the Welsbach light gives less satisfaction with a rich than with a lower quality of gas, measured by total calorific power. They also show how it is that in practice a gaseous fuel

of comparatively low calorific value, carbon monoxide, owing to its small air requirement is capable of yielding certain results, as steel welding, more conveniently than a high-grade petroleum oil gas, the air requirement of which is large.

CHAPTER XIII

FUEL APPLICATION OF GAS

It is now possible to set in a clear order the principal fuel applications of town's gas, which cover all its uses except that of giving light by its self-luminous flame, already sufficiently defended as the distinguishing characteristic of this public supply service.

It is to be regarded as axiomatic that the calorific valuation of gas is, subject to realization, its practical fuel value also. This statement is not in contradiction of what has been said before as to the intensity of the combustion process levelling up in a certain way the calorific difference between different gases. The truth remains that the total heating power of a gas is represented by its calorific measure, and that for certain purposes this is its predominant quality.

An example in point is furnished by such applications of town's gas as involve the use of the total heat-value per cubic foot, without reference to the flame, or, as it is preferable to describe this quality, the combustion intensity. For these purposes the gas may be burnt indifferently either as a luminous flame, or Bunsenized by a preliminary addition of a proportion of air well below the explosion point. Thus for heating a cooking oven, or roasting chamber, in which the gas is burnt as a free flame, without contact with the sides or bottom of the chamber; for "geysers"; for stoving metal objects by dry heat; or warming the air of an interior, it is clear that the quantity of gas required for the purpose will vary inversely as the total heat value of the fuel. If this is known the proportions of the gas-consuming apparatus can be adjusted accordingly. No

disposition of the burners will affect the result ; since where the gas burns freely in the atmosphere, with which the products of its complete combustion mingle, imparting warmth which eventually reaches the containing walls, its effective duty is the maximum possible = 100 per cent.

For a great many purposes this simple principle of utilizing the heating power of gas is not possible, because a high-temperature effect, from the contact of the flame itself or its combustion products at their hottest is required. For this application the gas must be Bunsenized. The term perpetuates the name of the great chemist, Bunsen, who invented the method of producing a clean, smokeless flame for the use of his laboratory—threw it off, so to speak, without a second thought for its prospective utility. It is not putting the case too highly to say that without this remarkable device, the fuel uses of a hydrocarbon gas would be sadly limited. It is to be borne in mind that the process of Bunsenizing a gas does not add to its total fuel value—a point that practical gas-fitters grasp with difficulty—nor does it increase the temperature attained by the luminous flame ; but it enables the heat of the flame to be applied directly to the purpose required, without causing deposition of soot.

The method has other precious advantages : it is equally effective with large or small quantities of gas, Bunsen flames ranging from rates of hourly consumption of 500 cubic feet down to half-cubic foot, showing equal fuel efficiency. The structure of the Bunsen burner itself is simpler and less liable to damage by accident or wear than a luminous flame burner. The only delicate part is the gas nipple, which works in the cold.

The essential principle of the Bunsen burner consists in the admixture, before ignition, of air in the proportion

roughly, of rather less than half the theoretical volume required for the complete combustion of the gas, when working at atmospheric pressure. The effect of this admixture is to facilitate the combustion of the carbon *in* the flame, instead of in the outside skin of the luminous burner, where the process is easily upset by a cold draught of air or contact with a cold solid body, with deposition of the unconsumed carbon as soot.

The Bunsen as we now have it is not the same as Bunsen made. That was a device in which a hollow vessel, having the form of a short, upright hollow cylinder standing upon projecting feet to allow the air to enter, was covered at the top by wire gauze. The gas was admitted at the side, through an ordinary lighting burner. Thus the gas and air mingled freely inside the cylinder, and the flame occurred on the upper side of the gauze. The modern Bunsen consists of an injection nipple for the gas, escaping centrally in a suitably proportioned mixing tube with regulated air admission, so that the resultant flame is under control both ways. The effect of this control is to modify the character of the flame between the extremes of " keen " and " soft," the difference proceeding from different proportions of air admitted as " primary air," as it is called.

With the " keen " flame an inner green cone of hissing fire appears on the burner orifice, and the remainder of the flame is comparatively short and stiff. This is the hottest flame of the kind, and the upper portion, above the top of the green cone, is " solid"—meaning that it is burning all through alike, without hollow interior. A very little more primary air will cause the gas to " light back "—to ignite at the nipple—owing to the mixture approaching too near the explosive limit. In the opposite condition, of the " soft " flame, there is no visible inner cone, but the whole flame is flaccid,

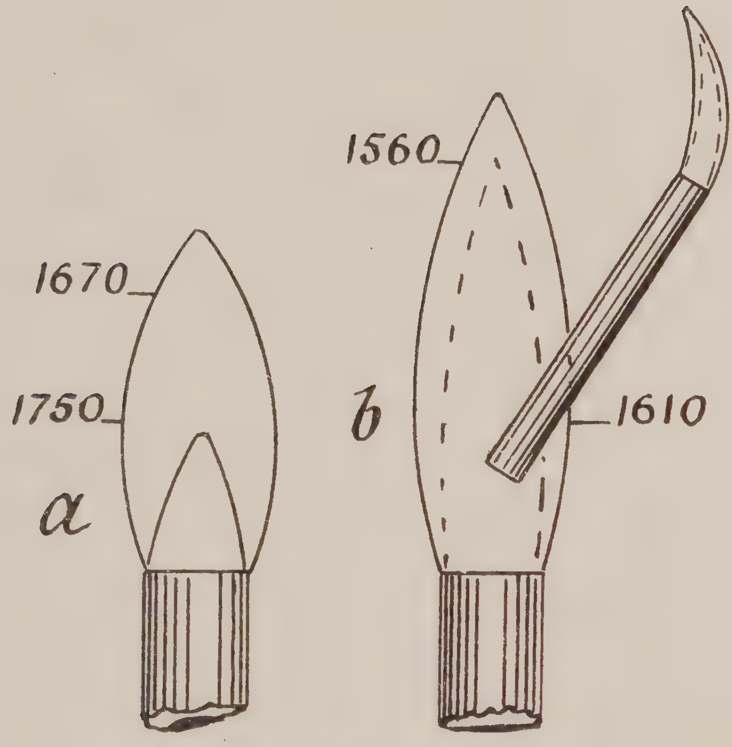

FIG. 12

CHARACTERS OF BUNSEN FLAMES

Fig. 12*a*, is a diagrammatical representation of a well-aerated, or as it is called in practice, a "keen" Bunsen flame, showing a short hissing inner cone. Inside this cone there is no combustion, only a quite cold mixture of gas and the "primary" air. Combustion is completed in the outer conical flame, by the action of the external or "secondary" air. The upper portion of this flame is said to be "solid"—meaning that it is in active combustion all through, so that no unburnt gases of imperfect combustion can be extracted from it, either by a tube, as in *b*, or as an effect of contact with a cold solid body. This kind of flame, therefore, should alone be employed for heating by "contact." The "soft" Bunsen flame, *b*, shows no distinct inner cone. It is hollow throughout, as indicated by the dotted line, and a tube introduced into its interior will extract combustible gas which can be ignited. When such a flame impinges upon a solid body, this gas escapes into the atmosphere with an offensive odour. The figures indicate the temperature, in degrees centigrade, found by Lewes for these points in the flames.

of a uniform lilac colour. Its temperature is lower than that of the keen flame, and it is hollow. If a cold solid, such as the bottom of a pot or kettle, is brought into contact with such a flame, the effect is to prevent the unburnt gas from the hollow inside from burning at the outside of the flame, and this therefore escapes into the air and smells badly. This evil smell of a smothered Bunsen burner is a frequent result of bad design of the burner, and of the want of sufficient space between the burner and the bottom of the vessel to be heated. It need never occur in sound practice, although it has been so common that people grew resigned to the infliction as inseparable from the use of gas by this means.

Thus it follows that the same maltreatment of a gas flame, by smothering it with a cold, solid body or exposing it to a sharp draught of air, which causes the luminous flame to smoke, causes the soft Bunsen flame to smell badly, and from the same cause, namely, interference with the normal burning of the flame.

Valuable as the Bunsen principle of burning gas for fuel purposes is, the burner and its adjustment call for intelligent understanding, to avoid unpleasant accidents. The lighting of the burner requires some care, especially if the gas tap is at some distance from the actual burner, in the case of a horizontal mixing tube, in order to prevent the lighting back of the gas at the nipple, or a " bang " due to the formation of an explosive mixture of air and gas in the tube. Both of these accidents are caused by mistaken handling—the former by applying the light too soon, and the latter by being too late with it after turning on the gas. They are liable to occur with the best designed and regulated fitting ; but are of no importance provided the lighter knows the causes and their prevention. Lighting

back after ignition, which may be caused by a drop of gas pressure, or by a draught of air when the flame is turned low is to be guarded against, for the reason that it will choke the apparatus with soot. Usually however, it makes a peculiar noise in the burner tube, which is calculated to attract notice.

One of the merits of the Bunsen burner is its amenability to modification designed with the object of realizing practical advantage from the quality of intensity in combustion, already distinguished from the total calorific value of the gas as fuel. This is done in the ordinary way, with gas at the customary low-working pressure of about 25 tenths, and at atmospheric pressure, by particular design of the gas injector or of the mixing tube, or of the burner orifice. It has been explained that a gas of moderate air requirement, as modern 500 therm. gas, mixes more readily with air in a short Bunsen tube, such as that of the Welsbach mantle burner, than a gas so heavy with carbon that its air requirement is great. Now, the Welsbach principle of making a light from gas deprived of flame luminosity, by causing it to heat up to incandescence a " mantle " of fine refractory material, calls for both fuel value and intense combustion. Possibly it was failure to grasp this truth which led to past disputes amongst theorists as to whether the gas flame was hotter than the mantle, or the mantle hotter than the flame. Seeing that the mantle derives its temperature from the flame, it seems the logical conclusion that the flame must be the hotter ; because it is absurd to think of an effect as greater than its cause, and because the mantle is constantly radiating heat which the gas has to supply; which is all quite reasonable, yet fails to explain why the mantle radiates a bright white light, assignable to a temperature in the neighbourhood

of 2,500° Fahr., whilst bathed in a Bunsen flame only measuring a temperature of about 1,600° Fahr. which corresponds to " cherry red " in the colour scale.

Without pretending to decide this knotty query, it is possible to perceive that intensity of combustion upon the mantle must exert an important influence upon its activity as a radiator of borrowed heat. It has been found that a thorough mixture of the primary air and gas increases the brilliancy of the mantle. In the " Kern " improvement of the Welsbach burner a Venturi tube (double cone) form was given to the tube, which thereby took in more primary air and dispensed with the chimney, gaining 25 per cent. of luminosity. In the " Selas " system of lighting, a mixture of equal volumes of gas and air is mechanically formed and forced through the nipple of the burner, drawing in a larger volume of primary air. It is possible to increase the primary aeration of a Bunsen flame to the total quantity of the air of combustion (four or five volumes to one volume of gas) if the velocity of forward flow of the mixture in the tube is greater than that of the explosion wave striking backwards. This can be easily done by mechanical compression, so that the most highly explosive mixture burns quietly at the end of the tube. By the same means the quantity of gas which can be burnt in a mantle of a certain size is largely increased, with a considerably enhanced brilliancy of incandescence. The mantle efficiency appears to increase directly with the pressure, although not in a regular ratio.

The same gas which gives light at the rate of 12 candle power per cubic feet per hour at ordinary district pressures of about 25 tenths will give five-fold the quantity of light under a pressure of 64 inches of water, with a mantle of identical composition.

There is no determinable relation between the calorific measure of a gas and its illuminating value with the mantle light. Thus a gas of low calorific power may be as good for this purpose as a better sample, from the fuel standpoint, provided that the air adjustment is properly made. If a strong fuel gas is replaced suddenly by a poorer sample, which may happen in a time of emergency, the result is likely to be some complaint ; whereas by reducing the admission of primary air to the burners the light would be restored to the customary brilliancy. The same with gas fires, or cookers : the air adjustment is quite competent to compensate for any alteration of the quality of a town gas supply likely to arise in everyday practice, or in the event of a consumer moving from one gas supply district to another and taking his gas fittings with him.

CHAPTER XIV

GAS LIGHTING BY INCANDESCENCE

It will probably be expedient to say something here about the incandescent gas light. There is a popular idea that the use of gas for lighting is dying out under the competition of electric light ; which is far from being the case. Gas light is cheaper than electric light, as the following comparison demonstrates :—A moderate-sized dining-room will be well illuminated by a 50 candle-power lamp hung on the table. An inverted incandescent gas burner will give this amount of light for a consumption of four cubic feet per hour. Assuming the constant use of the room for 2,000 hours per annum, this means a bill at, say, 3s. per 1,000 cubic feet amounting to 24s. for gas, *plus* 1s. for mantles—25s. in all. A good tungsten incandescent electric lamp of equal power will account for 100 watts of current per hour, or 200 Board of Trade units a year *plus*, probably, the price of one lamp. The price of current to private consumers varies greatly ; but it is safe to observe that it is rarely to be had for as low a charge as 1½d. a unit, which would put it on a par with the gas. Hence both for small householders and large establishments the cheapness of gas light is bound to tell. Where the electric light is most appreciated is for short periods of use, which reduce the importance of the time element. The same consideration applies also to the effect upon the eyesight of the method of lighting, gas light being far less fatiguing over long hours than the more intense light of the incandescent electric filament. The argument against gas on the ground of its absorbing oxygen from the atmosphere

fails against the fact that the absorption is insignificant in quantity. If, as stated already, gas requires from four to five times its bulk of air to support combustion, the domestic inverted burner in this case will require the oxygen of 16 to 20 cubic feet of air per hour, replacing the same with one-half of its own bulk of CO_2, which is not a poison but an inert gas incapable of supporting combustion or life. It is, however, a regular component of the atmosphere in the proportion of about four parts in 10,000. Assuming the cubical content of the apartment to be 1,500 cubic feet, and the air to be changed by ventilation four times in the course of an hour, this works out to 6,000 cubic feet of air to which two cubic feet of CO_2 is added by the burning of the gas, bringing up its CO_2 content to 7·3 parts in 10,000. This amount of carbonic acid gas in the atmosphere is far below that found in any crowded interior, with or without artificial light of any kind. As a matter of fact, the heat of the gas lighting burners is a good aid to the ventilation of crowded halls, churches, and so forth, as tending to keep the foul air in circulation upwards above the heads of the people, where it can be dealt with by extraction.

The Welsbach incandescent gas mantle of commerce is a remarkable example of science, invention, and technical skill applied to the production of an absolutely novel article. The idea of obtaining light from a non-luminous gas flame by the method of incandescence was not new. It had been tried with platinum-foil as a solid radiant, as in the analogous case of incandescent electric lamps; but failure resulted from the same reason, namely, that at the temperature necessary to give a useful degree of luminous radiation the metal melted. Welsbach succeeded with gas heating because he found a mineral sufficiently refractory at the high

temperature required, to stand the heat for a satisfactory length of time. This material was thoria, the oxide of the rare metal thorium; but for some reason not hitherto explained, a minute fraction—$1\frac{1}{2}$ per cent.—of the less tenacious substance, ceria, must be present to render the whole serviceably luminous at the temperature of the Bunsen flame. A dip solution of nitrates of thorium and cerium in due proportions is caused to saturate suitably shaped fabrics of ramie thread, which burns away without leaving an appreciable amount of ash; and the result is an illuminant many times more brilliant than the native hydrocarbons of the gas flame.

This is not the place to go deeply into the science or the practice of artificial lighting; but the following general hints may be useful to handworkers, readers, and writers :—

1. Have plenty of light for your purpose; it is cheap enough.

2. Have the light upon your work, not into your own eyes.

3. Avoid too great contrasts of light and shade. The reading lamp is a relic of barbarism. Light up the whole room, with more if necessary close at hand for fine work.

4. A glaring light, harmful to the eyes, is not always a too bright light, but is always a light in the wrong place.

In normal times a big business is done in high-power lighting of important centres of street traffic, for shop displays, etc. The gas is supplied under increased pressure, when the luminous intensity is raised to 60 candle-power per cubic foot of hourly consumption, at very little extra cost for compression.

CHAPTER XV

COOKING BY GAS

The first important domestic application of gas as fuel was for cooking, and this is now one of the largest branches of gas companies' business. In most gas supply areas an ample selection of cooking apparatus is to be had on hire from the company, or is purchasable on easy terms. Instruction in the proper use of every variety of consumers' gas appliances is usually given ; for the companies realize that a satisfied consumer is an excellent advertisement. With respect to cooking stoves pure and simple, certain hints as to selection and use may not be thrown away. Gas, it should be remembered, should not come more expensive in the kitchen than coal ; whilst it is infinitely more convenient, more certain in operation, lends itself to better and more economical cookery, and is an enormous labour and time saver. Work in a gas kitchen should go like clockwork. Waste of gas, however, is very easy, since the cocks will not shut themselves off when done with. The ordinary family gas cooker consists of an oven, a roasting chamber, a number of boiling burners, and a griller. Smaller arrangements can be had for individual requirements ; and, on the other hand, no canteen or club is too big for a complete battery of gas-cooking apparatus. The family cook and caterer will be well advised to choose a stove of sufficient size. The oven part is always to be heated up by lighting the gas full on for at least ten minutes or a quarter-of-an-hour before use ; when, as a rule, the gas flames can be lowered to one-half for the period of cooking, as advised. A certain amount of condensation

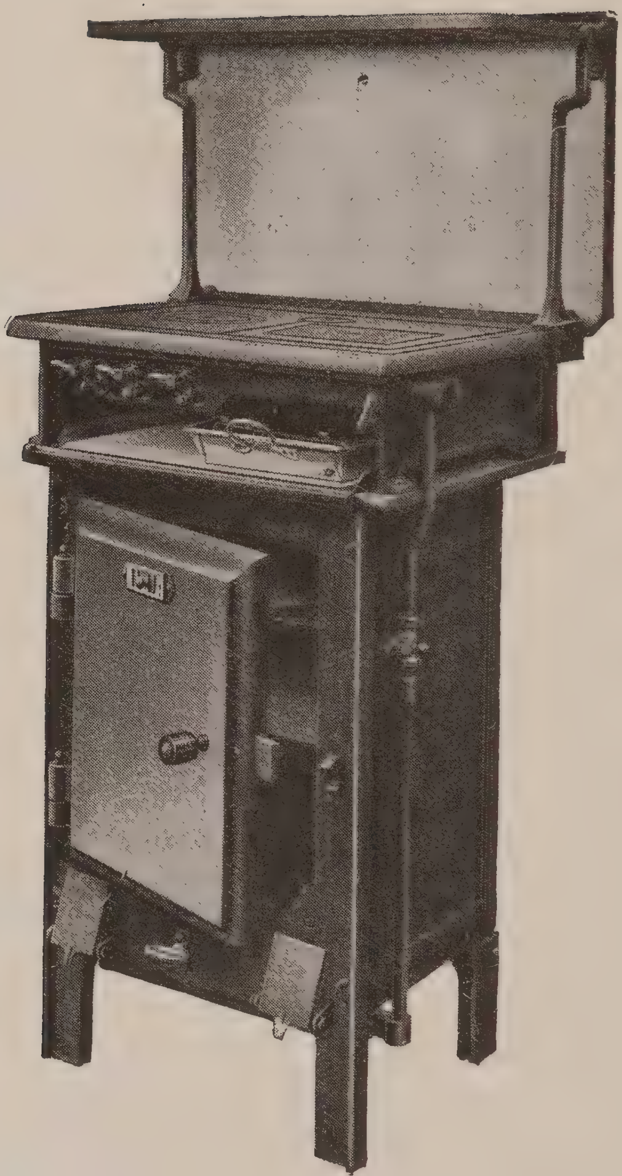

Fig. 13.

A GAS COOKER MODEL

of moisture occurs when the hot products of the combustion of gas (which contains aqueous vapour) strike cold metal ; but this, of course, ceases as soon as the condensing surfaces attain a temperature above 212° Fahr., the boiling point of water.

The secret of economy of gas in cooking lies in the careful adjustment of the means to the end. It is the boiling burners which run away with the bulk of the gas consumed in cooking. There are burners of different sizes on the complete gas cooker, and a thoughtless or uninterested user can very easily waste double the quantity of gas really necessary for doing the work in hand. Equally, a careful person can do better with a gas of lower grade, technically speaking, than another with a nominally stronger fuel, which probably costs more.

A query that has been ventilated in the newspapers relates to the cost of boiling by different fuels a unit quantity of water—say, a quart. The facts, for what they are worth, are as follows :—

To raise one quart of water, weight $2\frac{1}{2}$ lbs., from a temperature of 60° Fahr. to 212° Fahr., represents the absorption of 380 therms. This, therefore, is the irreducible heat minimum, and a fuel and a means of applying it which should realize this figure would show 100 per cent. efficiency ; which is impossible.

If the heating were by electricity, which has a theoretical calorific power of about 3,440 therms. per B.T.U., about one-eighth of a unit would furnish the quantity of heat required, on a basis of 100 per cent. efficiency, subject, in practice, to realization by the apparatus employed. Assuming this to have an efficiency of 50 per cent., the actual consumption of electricity to boil a quart of water would amount to $\frac{1}{4}$ unit, nearly.

If the fuel were 500 therm. gas, carefully used, with

an efficiency of apparatus in the neighbourhood of 50 per cent.—a quite easily realizable figure—the consumption of gas would be about 1½ cubic feet.

On the other hand, the consumption per quart of gas of 550 therm. calorific value may amount to 1½ cubic feet, with a quite ordinary lower efficiency of operation. Loss of efficiency in this case need not proceed from carelessness, but from the use of an unsuitable vessel, or too large a burner. With careful handling a gas of 450 therms. will prove as economical as a sample of a considerably higher calorific figure, altogether apart from carelessness in the use of the latter.

CHAPTER XVI

WATER HEATING BY GAS

WHAT the above observations, which are based upon direct experiment, mean is that in order to realize the highest possible economy from the domestic use of gas as fuel in cooking, with especial reference to the boiling of water, which represents 80 per cent. of all culinary operations, it is necessary to keep a good watch over the proportions and control of the apparatus used. Experiment demonstrates that there is a relation between the rate of gas consumption, the dimensions of the vessel, and the quantity of water which yields the maximum efficiency for the purpose. This maximum does not appertain to a particular quality of gas, as measured by its calorific figure ; but the description of gas denominated in this book 500 therm. gas appears to be a "happy mean."

It was some years after the successful popularization of the gas cooker that attention was given to the problem of the application of gas to the heating of water in bulk, as in domestic hot-water circulatory systems. The first attempts in this direction were of the class of rapid bath-water heaters known collectively by the name of "geysers." They aimed at supplying the need of premises destitute of the plumbing attached to the fixed bath and the circulating boiler at the back of the kitchen fire ; and are quite successful in this regard. The simpler form of geyser is a single-point affair, supplying the hot water for a bath situated immediately beneath its outlet pipe. So far as efficiency extends, it is an admirable way of heating water by gas. It is practically a gas calorimeter, extracting from the

burning gas the maximum amount of heat consistent with the evacuation of the products of combustion by the flue pipe. This, however, presents some difficulty, and the question of ventilating the bathroom containing a geyser burning a large quantity of gas in a short period of time calls for careful treatment.

It was not until the application of gas heating was tackled in connection with the skilful plumbing of modern fixed hot-water circulation systems that the system became really popular, and the coal-fire kitchener with its boiler was definitely superseded by gas. There are at present in the market several serviceable gas water-heaters adapted to work in connection with existing circulatory systems, and to a high rate of efficiency these add ingenious arrangements for self-regulating when the temperature of the water rises beyond what is required for the purpose, which is very necessary, as water should never be allowed to boil in a system of this kind. All such systems should be overhauled and cleaned out once a year—oftener in districts supplied with very hard water.

(NOTE.—*The details of domestic hot-water circulating systems, etc., are treated fully in the author's manual, "Gas Supply in Principles and Practice." Sir Isaac Pitman & Sons, Ltd., London, Bath, Melbourne, and New York. Price* 3*s.* 6*d.*)

CHAPTER XVII

GAS FIRES

The use of gas for warming dwelling-houses and other interiors is rapidly extending, by reason of the economy of labour, superior cleanliness, convenience and adaptability of the method to an immense range of domestic and business requirements. The appliances designed for this purpose belong to two classes—"total heat" and "radiation" devices, with hybrids between the two. The total heat applications depend upon the free burning in the atmosphere of the interior of gas, without special ventilation provision for the removal of the products of combustion. As previously remarked, these are 100 per cent. efficiency devices. Although exception has been taken to the employment of these fitments in occupied rooms, the matter reduces itself, upon unprejudiced examination, to a simple issue: If the interior is properly ventilated generally so as to be suitable for occupation by the ordinary inmates irrespective of whether it is artificially lighted or warmed, or not, the extent to which its atmosphere would be prejudicially affected by the discharge into it of the combustion products of the quantity of gas required to light, or "take the chill off" in cold weather is negligible from the hygienic standpoint. All that is necessary in such a case is that the gas should be properly burnt, without such contact with any solid part of a "stove" as to cause the discharge of partially consumed gases, as already explained with reference to the proper adjustment of Bunsen burners. For this reason, simple arrangements of luminous gas flames are to be recommended, as there is no likelihood of these

going wrong. Makers of gas "stoves" employing Bunsen burners are not to be implicitly trusted to observe this condition, and gas-fitters are not seldom ignorant of it. The sole utility of these non-ventilating gas "stoves" is their localizing the immediate heat of the burning gas in their own neighbourhood, with the advantage of a "cheerful appearance." Really, however, for entrance halls, shops, and all interiors where there is a continual coming and going, plain gas warming of the air to a moderate temperature of, say, 55° Fahr. when the outer atmosphere is anything lower, can be secured in the simplest way without the least inconvenience. Often the question is one of alternatives.

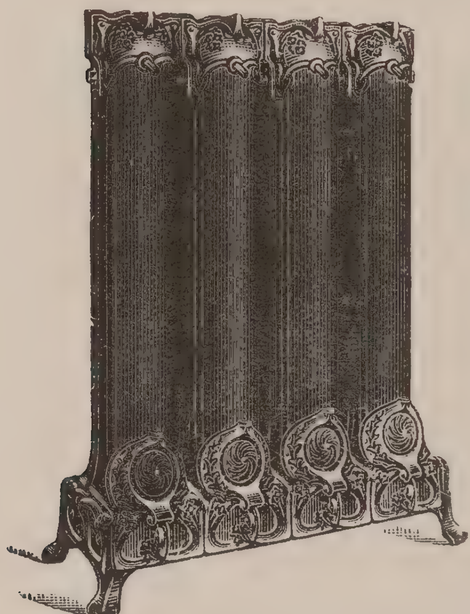

Fig. 13

FLUELESS HALL OR SHOP AIR WARMER

The specific heat of air—*i.e.*, its capacity for absorbing or losing heat—is small, being 0·02 therm. per cubic foot. Hence for every 1,000 cubic feet of air raised from 35° Fahr.—the outside temperature of a "raw day" in the British winter—to 55° Fahr., 200 therms. are required ; which is the total heat of two-fifths of a cubic foot of gas. Consequently quite a capacious shop or hall could be rendered habitable at the cost of a small quantity of gas used in this way. For an interior which will be closed during occupation, such as a church, court of law, or crowded workshop, the warming might be done by night, and the gas shut off

by day, which would prevent the stuffiness commonly experienced in such places when artificially warmed during use.

Something different is demanded for domestic warming (although a free gas burner or two in the entrance hall even of the small house is a great comfort in cold weather); and this is supplied by the gas "fire" warming a room by radiant heat, precisely the same as a coal fire. This method, involving ventilation by the chimney, entails a much larger proportional consumption of gas. The efficiency of the best modern gas "fire" in respect of the proportion of the heat of the gas realized as radiant heat, is about 50 per cent., which is equal to the proportional heat radiation of a bright coal fire. Since the cost of the gas fuel is greater than that of raw coal, the expense of the two sources of heat is unequal.

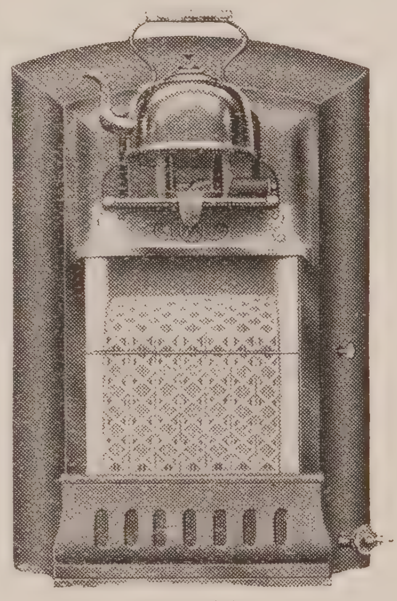

FIG. 14

GAS FIRE WITH "NURSERY" BOILING ATTACHMENT

Heat for heat, the gas fire must cost more per hour than a coal fire of equal power; for which reason the former is chiefly used for short periods, or for sick rooms where its noiselessness and constancy are invaluable. If the element of labour in carrying coal, removing ashes, cleaning the grate, etc., and sweeping the chimney is taken into consideration, the great and growing popularity of the gas fire is easily understood. A working rule for the size of gas fires in

proportion to that of the apartment is to allow for a gas consumption at the rate of 15 cubic feet per hour to 1,000 cubic feet of space, for rooms of small to moderate dimensions. Very large rooms require air heating in addition to radiant fires.

Thus, the all-gas house is pre-eminently a time and labour-saving institution, and the absence of smoke from its chimneys makes for the brightness and cleanliness of the town in which it stands. The last touch of sanitary service rendered by gas in the household is the domestic refuse destructor, which makes the dustman as superfluous as the sweep.

CHAPTER XVIII

THE INDUSTRIAL USES OF GAS

THE industrial and trade uses of gas are literally too numerous to mention. The technical literature of the subject is voluminous, and rapidly opening up fresh ground. When the war needs of the Allies in 1915 turned Britain into one huge arsenal, it was the gas industry of the country, larger and more highly developed than that of any other country, which lent itself immediately to the effectual solution of the tremendous problems of manufacture that faced the new Ministry of Munitions. The full story of what was done in the emergency can never be told ; but it is certain that if it were, the chapter relating to the part played by gas would be one of the fullest and most creditable to the initiative, ingenuity, and enterprise of all concerned. The peculiar point in this connection is that when every factory, large and small, turned from the making of mineral-water machines to the production of shells, or gave up stamping match-boxes to fashioning bombs, the necessary additional fuel supply was already at the door.

Gas compressors previously used for high-pressure lighting were put to work in melting metals, welding, stamping, forging, and tempering weapons and munitions of war. A remarkable number of gas workshop appliances of peace were found quite suitable for warlike purposes, and the conversion of the *materiel* of the industry in this regard proved as quick and effective as the contemporaneous transformation of the alert gasfitter and his mate into good soldiers.

It would be beyond the purpose and scope of this little book to enumerate the industrial applications of

gas, which are more or less highly technical. What is to the purpose is to remark that so far as can be seen into the industrial future, there is not in this, any more than in the domestic sphere of utility, any indication that the broad lines of the existing gas industry are likely to be changed. Coal, and when the conditions again become normal, mineral oil, will continue to be carbonized for the production of a self-luminous gas, which will be distributed after purification, and possess much the same fuel characteristics as the actual product. The standard of serviceable value will remain as at present, although differences of manufacturing methods will come into operation as the conditions of labour and other cardinal points of the industry dictate. There is not in sight, or in the dim perspective of theory, a more economical use for coal; which is the conclusion to be demonstrated before a change is to be looked for. The writer sees no reason to doubt that the regime of high carbonization of the raw material, with a standard 500 therm. gas, 85 per cent. combustible, reasonably purified, distributed at a minimum of three inches of water-pressure at the consumers' meters, will continue for so long as it is prudent to prophesy; by which time all towns enjoying such a service on fair terms should be smokeless.

The part played by gas, or rather by gasworks, in the production of mechanical power is somewhat difficult of comprehension by the non-technical mind. Passing mention has been made of the application of gas as a source of motive power, and the enormous importance of this kind of prime mover can hardly be exaggerated.

It may be doubted whether the whole order of internal combustion heat engines—prime movers in which the

FIG. 15

GAS-LIGHTED LAUNDRY, WITH GAS IRONS (HIGH PRESSURE)

working "fluid" is formed and operates inside the engine cylinder—would have arrived at the present development of the type on the earth, in the water, or in the air without the facility afforded in the first place by the simple, uniform coal gas. Although the gas engine working on town's gas fills a prominent place in industry, and has successfully superseded steam engines of all sizes, its interest has suffered considerable eclipse by the attention bestowed upon the younger members of the family—the oil engine, the petrol motor, and the big blast-furnace gas engine. Compared with these, the common town gas engine is a humdrum proposition. It holds its ground, however, notwithstanding the strong commercial competition of the electric motor on the one hand, and of "suction gas" power plant on the other. Surprise is sometimes expressed that the gas engine in some one or other of its forms has not ousted the steam engine more completely, by virtue of its higher economy, and smaller need of constant attention. It is pointed out that whereas the common kind of small factory steam engine consumes anything from 7 lbs. to 12 lbs. of coal per indicated horse-power hour, as compared with the Lancashire mill standard of 2 lbs., and is usually considerably below par as a machine for converting steam into work, thus showing an average fuel duty of under 10 per cent., a very ordinary gas engine easily averages a fuel duty of from 25 to 28 per cent. The freedom from coal cartage and storage, labour of a boiler attendant, clinker and ashes removal, and liability to prosecution for smoke is another advantage of the gas engine; which is ready for work at a moment's notice and has no stand-by losses.

There are many more or less weighty reasons for the retention of the inefficient steam engine which go to

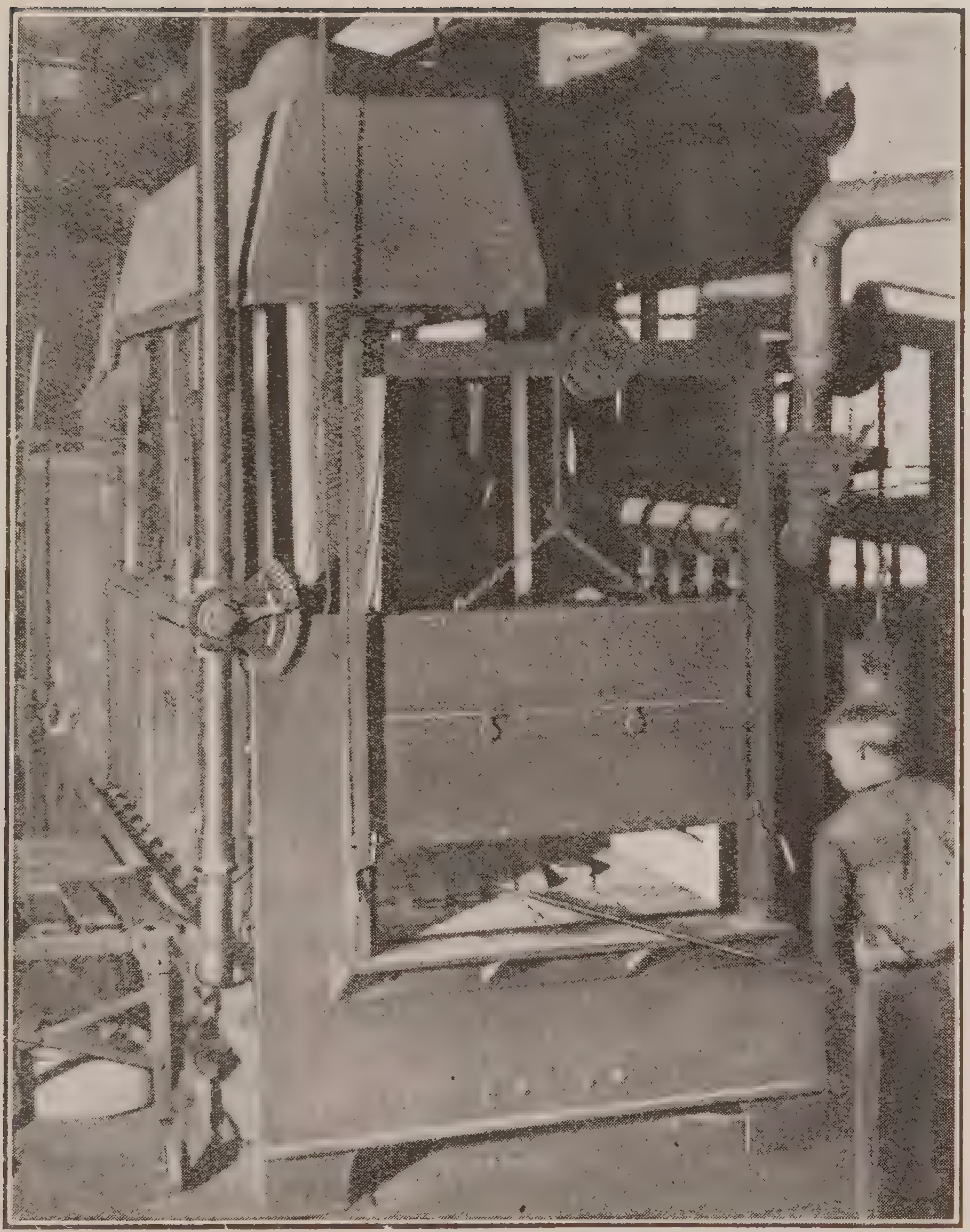

Fig. 16

CUPRO-NICKEL ANNEALING FURNACE

explain the fact. Mere inertia is one of them, added to consideration of the cost of scrapping and replacement. The uneconomical steam-power comes cheap in fuel, at ¾d. per horse-power hour, with coal at 20s. per ton—another example of the divergency of commercial and coal economy. An odd man, perhaps an old servant unfit for much else, looks after the boiler and engine. Assuming a gas consumption at the rate of 20 cubic feet per horse-power hour, the fuel bill with gas at 3s. per 1,000 cubic feet, *plus* meter rent, would be the same. Where the gas engine scores commandingly in towns is in respect of the generation on large premises, as textile mills, general department stores, factories, banks, etc., of electricity for lighting during short periods of winter and dark days. This is a class of lighting business not appreciated by the public electricity supply undertakings. On the other hand, the provision of power over long periods is business which the same undertakings are greedy after at almost any price, and they will underbid the gas supply with the even greater convenience of the electric motor. Hence at the present day when users of small to medium power for regular working have the opportunity of scrapping an old steam engine, or for new plant, the electric drive gets the preference.

In recent years a strong bid for this class of business was made for so-called "suction gas" plant. This is a kind of producer gas made as required by the engine drawing air, with a little aqueous vapour added, through an incandescent mass of carbonaceous fuel, preferably "pea" anthracite in a closed furnace. On paper, the economy of the method is high, and with care and a regular supply of suitable fuel the working is quite good; but there are drawbacks sufficiently serious to check the development of the system on an important scale;

There must be a producer to every engine ; the use of a gaseous compound containing a large proportion of deadly poison is hazardous and difficult to defend on the only pertinent ground of cheapness ; the starting-up practically necessitates the addition of a stand-by supply of town's gas, also indispensable in the event of defective production ; the coal consumed is sulphurous and liable to cause a nuisance to the neighbourhood, involving risks of disastrous law-suits. On the whole question of gas power, therefore, save for exclusively industrial situations, where nothing in the way of amenity matters, it is better to make use of the purified town's supply of the character and quality already set out in the preceding pages.

CHAPTER XIX

SPECULATION AS TO THE FUTURE

It has often been suggested that the future requirements of the country for largely increased mechanical power, coupled with the desirability of coal conservation, could best be met by the creation in selected localities possessing the necessary coal and water facilities, of very large electrical-power generating stations, in regard to which gas manufacture would be relegated to a very subordinate place, if not wholly superseded. The writer is of opinion that the more economical solution of the problem of producing such mechanical power as the country really requires lies in a directly opposite direction—in the development of scattered gas-producing stations in conjunction with electric power generation. The concentration of industry in particular regions, for no predominant necessity of the industry itself is an evil. The decentralization of productive work, so that as far as practicable all the population of a country shall be able to find proper employment at or near home is a sounder proposition. If this principle is approved on general grounds of public policy, hygiene, and social advantage, the question of scattered power facilities appeals for a favourable answer. Such an answer lies within the reach of a reasonable industrial policy not swayed by advisers committed to preconceived ideas. The first term of the equation is the treatment of the coal to the best advantage, the next is transmission or distribution of the products, the third is their utilization. It is necessary in approaching the general problem to observe the distinction between present commercial, and permanent

national economy. For example: The factory owner requiring large electric power may save running expenses by setting up his steam generation plant on a coal-field, where he can get his fuel cheap. This is not necessarily the way to economize the coal itself—probably the contrary; because it will cost so little that it may be cheaper to burn it wastefully rather than incur the expense of every known means of saving fuel, such as would be employed where the coal is dear. The same line of criticism can be pursued through a whole industry, including the question of man power. It may be cheaper to employ on a certain job an able-bodied man than to get the work done by two women; but clearly this is not the last word on the subject.

It by no means follows that the biggest steam-power station has the lowest running expenses, apart from such factitious advantages as that of locality near a coal supply. There is a mean running efficiency, which is found at a quite moderate size of boiler and engine construction, beyond which mere magnification is more likely to bring increased trouble and anxiety than profit. After the generation comes the transmission and distribution; and this, again, is a question of relative advantage. Power transmission and distribution is the most favourable to the electrical medium, because the electric drive of machinery is the most economical application of this form of energy; but even this has to justify itself against the competition of locally generated mechanical power. As regards the production of light and heat, electricity is hopelessly uneconomical from the point of view of coal conservation, not more than 3 or 4 per cent. of the original heat energy of the coal fuel being realized by an electricity distributing system in the forms of light or heat. In this case, also, the invaluable by-products of coal carbonization are lost.

Owing to the parliamentary severance of electricity generation and supply from gas manufacture and supply, the potentialities of gasworks as coal conservation centres have remained largely unrealized. They are only dormant, however, and could be vitalized in far less time, and at much less risk of financial disaster than the grandiose schemes already referred to, which would start with the disadvantage of having to find the market for their commodity.

Moreover, gasworks whether treated as independent manufacturing units, or grouped for specialization—which might be very successfully arranged in many districts,—would be found much more elastic in their methods and products than circumstances have ever permitted. Hard, metallurgical coke, ordinary gas coke in all grades, briquettes, and soft, flaming char could all be made where the markets for these varieties of solid fuel existed ; and it would certainly be cheaper to carry the coal to the place of carbonization than to handle these products separately. Producer gas does not pay to transmit to any distance ; but possibly some use for this form of fuel could be found in the neighbourhood of gasworks ; and a quantity of steam could also be had there as a by-product, for use in electricity generation. Localization, in contrast to centralization, is the sounder principle on all grounds—national, social, political, economical, and financial. But, like all good policy, it calls for prudent carrying out, with consideration of all pertinent interests and conditions.

A short enabling Act of Parliament might be agreed to facilitate the realization of the measures of economy above indicated. Hitherto the processes of municipalization and amalgamation of gas undertakings have been pursued with particular and limited objects,

amongst which the true interests of the communities concerned have not always been recognized nor subserved. For example, the fundamental divergency of municipal and company gas finance is indefensible on any ground of sound policy affecting the public interest in a cheap and satisfactory gas supply. As regards British gas companies, the wisdom of our forefathers who framed the Gasworks Clauses Act, 1847, has proved superior to all foreign inventions with a similar intention. That Statute limited the profits of the undertakers to what was deemed a reasonable return, with good husbandry, on the original capital of the adventurers, and also on any additional capital raised for extension of the business. This was the protection of the public. The protection of the investor was the grant of a maximum price for the gas. As already remarked in the introductory pages of this book, there was nothing in this plan of control to preclude competition, which was as a Damocles' sword over the older gas companies, but eventually proved a too costly means of applying "ginger" to the administrations of the established concerns. Subject to the Act of 1847, and the amending statutes, public and private, the property in gas stocks is freehold, and with few exceptions non-redeemable. On the other hand, when a gas undertaking is municipalized, the property is capitalized as a loan repayable within a limited period, like all other local sanitary authorities' commitments. This principle is doubtless sound, as tending to make every generation of ratepayers feel the burden of their own indebtedness ; but it commonly has the unfortunate effect of burdening their gas undertaking with a purely factitious charge denominated "profit," as a liquidation of the imaginary "risk" of allowing the rates to be pledged for the repayment of the gas

loan. Where this course is not taken, and the gas loans are of long standing—that is to say, where the undertaking was municipalized in the early days of cheap money—the capital burden on the gas supply is likely to be lighter than in the case of the majority of gas companies. Even so, however, the municipalization of a gas supply is not necessarily a way of cheapening the public service ; for some of the lowest-priced gas in the United Kingdom is sold by gas companies. In any logical reconstruction of the British gas industry with a view to economy, this question of the remuneration of capital, and the burdens upon it, should receive unprejudiced attention.

The future of the gas industry is open to curious surmise. What is to be its place and part in the changed and changing circumstances of a social, economic, and industrial world which everyone expects to be very different in many important respects from the present ? Socially, the future is more than likely to bring much alteration in the general scheme of domestic life and labour. The "servant question" will be accentuated. A style of living in which the whole time and attention of half a dozen men and women is monopolized by one man or woman must pass away under the pressure of a standard of education pointing to and fitting them for a better employment. Money will no longer command such service. At the other end of the scale, the difficulty of finding intelligent, educated women willing to immure themselves in the occupations of single-handed domestic service will increase until the "slavey" of tradition becomes extinct. People will be constrained to conform either to a co-operative mould of domesticity, in which the necessary labour is regulated upon industrial principles, and the positions of "master" and "man," "mistress" and "maid,"

are sunk in the relations of employer and employed; or in the only alternative everybody must "do for" him or herself in private life. Each of these propositions may appear sweeping to the verge of the revolutionary; but they cannot be gainsaid.

Clearly, when people discover that the money their ancestors and immediate predecessors spent upon servants will no longer command the labour market, they will turn to other expedients for reducing the toilsomeness of self-respecting living. Public supply services will be increasingly extended and developed, and labour-saving appliances and methods will rise in the appreciation of all but a perishing minority of fogies.

These are general reflections, or anticipations which may or may not be justified in an equal degree everywhere at once. It is clear, however, from the example of the United States of America, that the servant difficulty will not be allowed to set back the standard of taste and refinement in private life. It will not be a case of going without, but of substitution, and of improved ease and increased comfort. It is amongst the most backward peoples where there is most servility, and the lowest standard of domestic economy and hygiene.

Apart from all such questions of degree, the prime necessaries of cooking, warming, and artificial lighting will always attend the homes of mankind; and these in civilized communities hark back to the origin, coal. "War," it has been remarked, "takes no heed to the economies"; and in his struggle for existence against the climatic and other inimical forces of his environment, man has hitherto taken small account of fuel economy. He has cut down forests to burn, until no trees remained to feed his fires; and he is getting through

the coal capital of the world in the same improvident spirit—more so, indeed, because trees can be planted on the bare places of the earth, whereas coal cannot be replaced.

The call for economy of coal has been sounded, and will become more insistent as time goes on. There are two notes in this appeal, of different meanings in the hearers' perception. One suggests the frugal use of fuel on the ground of the supply not being inexhaustible; and human nature being what it is, few will accept this reason as urgent so long as there is no difficulty in procuring a supply of any amount. The other call is that which touches the pocket. Increase of cost, all the world over, is the sole efficient check upon reckless demand. It comes into action very soon after the customary cost of the commodity has noticeably risen. The fringe of the trade is first cut off. People do with a little less than usual; but they go on using what they do buy in the same way as before. If prices continue to rise, substitutes are sought, and consumption is still further restricted. After a good deal more experience of this stage of forced economy, if the commodity happens to be not indispensable it will insensibly disappear from the market-place. People will forget it. If, on the other hand, it is a real necessary, or agent of a necessary of life, like coal, when it grows sensibly both scarce and dear those who are responsible for the maintenance of the welfare of the commodity begin to bestir themselves with a view to finding what can be done about it.

Coal is a means to an end, and in preaching economy of coal what ought to be kept steadily in view is the purpose for which it is required to be consumed. It is necessary also to distinguish between the economy of money and that of the raw material. The

responsibility of the heads of the community covers both, whilst the solicitude of the consumer is more directly concerned with the former. A whole community used to paying a big price for coal will not necessarily apply it more economically than another where it is cheap. Indeed, most of the progress of fuel applications has originated in coal-producing countries. It is these also which are most likely to entertain feasible proposals to improve the industrial and other applications of coal in the interest of material economy. The logic of it will appeal to them more intimately than to consumers who regard the commodity solely from the immediate financial standpoint.

Although it sounds like a truism to say that regard must be had to the purposes for which coal is consumed irrecoverably, not a few persons claiming a considerable degree of scientific perspicacity appear to perplex this issue by confusing means and ends. Thus, some will declare that the only proper use of coal is to generate electricity, as though that were all-in-all in this connection. But coal is very much more than something to burn under a steam boiler; and electricity is not the only form of energy needed for the service of man.

There are many varieties of coal, properly so called, and also of mineral combustibles which are not strictly coal, but are more or less valuable substitutes for it in various respects and under special conditions.

Our space will only permit of a very cursory survey of the actual and prospective uses and possibilities of such good classes of common bituminous coals as are suitable indifferently for burning in industrial furnaces, including those of steam boilers, for household purposes, or for carbonizing or gasifying; and by "good" coal is meant in this connection sufficient value as fuel to warrant shipment or carriage to a

reasonable distance. Anthracite, or "hard" coal, is suitable only for limited uses either by direct burning or gasification in a "producer." Its economy is therefore hardly worth discussing.

The prospect of effecting substantial economy of coal burnt for industrial purposes other than steam raising turns chiefly upon the possibility of effectively substituting for it either coke or fuel gas. If the question of expense to the user is to determine the issue, the prospect will be narrow and limited. Factories established in localities with the express object of obtaining unlimited quantities of cheap coal would have no interest in coal saving at the smallest additional trouble or expense. If a regimen of the strictest realizable coal economy were made general, all "bulk" schemes based upon merely eliminating the expense of coal transportation would be ruled out.

The Report of the Fuel Research Board of the Government Department of Scientific and Industrial Research (H.M. Stationery Office, 1917, *price* 2*d*.), remarks :—

"The only development which would satisfy all (these) needs simultaneously would be the replacement of a large proportion of the raw coal which is at present burned in boilers, furnaces, and domestic fires, by manufactured fuels prepared from raw coal by submitting it to distillation."

Up to the present time no conclusive affirmative reply is possible to the question of the commercial possibility of such development outside gasworks. Theoretically the thing should be feasible, and if the saving of all coal consumed as above were imperative for other reasons it could mostly be done in the way indicated ; but it is not possible nor reasonable to treat the financial or commercial question as negligible.

To make what would be a long story short, it may be reasonably judged feasible to try the matter tentatively in connection with the coal rationing of gasworks

and domestic consumers, with an invitation on commercial terms to local power users; somewhat on the following lines :—

In a selected area of mixed residential and moderate industrial character, fairly self-satisfying, not to say isolated, let all the bituminous coal after a sufficient notice be consigned to the gasworks. Only oil, coke, and anthracite to be permitted fuel imports.

The electricity generating station to be installed at the gasworks, using as might be determined gas power, or steam generated by hot coke gas, with coke breeze and waste retort-bench boilers. The saving would soon defray the removal expenses.

All coke made, except a small margin to be carefully watched and adjusted to the demand, to be converted into water gas and added to the coal gas, which should be made with particular regard to obtaining the best return in liquid residuals and extracts.

The gas to be distributed at the most suitable pressure for the general consumers' appliances, which should be skilfully overhauled and adjusted to a cheap grade of gas. Special high-pressure supplies to be provided as required.

An efficient Sales Department to be organized by the Public Energy Service, which would supervise all dealings in gas, electricity, or coke to the advantage of the consumer, who should be assisted in scrapping wasteful appliances and being properly equipped with new.

The local authority and any public welfare organization should be encouraged to economize fuel and save household labour by the establishment of communal kitchens, etc. In the rebuilding of business premises, and the remodelling of old dwelling-houses as tenements and in the creation of new housing accommodation,

regard should be had to taking full advantage of the Public Energy Service.

There is no material reason why, by a perfectly feasible development of high-pressure transmission, the advantages and the economy of fuel inherent in gas light, heating and power generation should not be extended throughout rural England.

CHAPTER XX

HINTS FOR GAS CONSUMERS: SUMMARIZED

Gas consumers ought to be constantly on their guard against waste, bearing in mind that the most economical and therefore satisfactory gaslight, gas fire, or gas cooking appliance is that in which the tap is turned off the moment it is not wanted.

Domestic servants are apt to be extravagant in this respect, leaving gas burners alight whilst not in use to save themselves the trouble of lighting up, perhaps in half an hour's time. The meter does not omit to register these moments of heedless waste.

Lighting burners, as a rule, are small consumers. The sources of heavy gas bills should be sought elsewhere. Gas fires are a great comfort in bedrooms; but they are often kept alight quite unnecessarily. Just as some people have a trick of not closing doors, drawers, etc., behind them, so they waste gas for want of thought about turning off the tap.

In the use of gas cookers, care should be taken to suit the power of the burner to the vessel required to be heated, and to give a reasonable period of time for its operation, as, for example, boiling water in a kettle or pan. Boiling burners should give a short, hissing flame when fully turned on, and the flame should never flare up round the vessel. Cooks may believe that a long, flaring flame means good heat; but it is quite the opposite. The short, sharp flame with its tips just touching the bottom of the pot will heat it in less time, with less gas, and complete absence of offensive smell, as compared with a flabby, long flame.

If there is a choky, objectionable "smell of burnt gas" in the house, from a lighted burner, it should be seen to at once. Servants not infrequently remove the grid top of the cooker in order to put the pot or kettle right upon top of the boiling burner, when time is short. This is a sure cause of bad smell, waste of gas, and a heavy gas bill. If a kettle of boiling water is wanted by a certain time, it is a saving of money to put it on half an hour beforehand, over a small burner turned low. Then when the water boils, it will not boil away rapidly. It is wasteful to use too powerful a burner with a small pot, which will often boil over if not closely watched.

An iron plate on the top of the cooker will enable two or more pots to be kept hot by one burner. Some cooks have the impression that soups, milk, etc., will not "burn" over gas unless the flame actually touches the vessel. This is a mistake, as it is the amount of heat rather than the height of flame that matters in such cases. An asbestos shield under the pot, if not an iron plate as above, is the best preventive of this mischance.

Utensils used over gas should be kept very clean, outside as well as inside, and especially the bottom. If allowed to get sooty over a coal fire, a considerable waste of gas will ensue. Notwithstanding popular beliefs to the contrary, all ordinary materials of which pots and pans are made—cast iron, wrought iron, copper, aluminium, enamelled iron—get hot in about the same time over a gas burner. Really, the quantity of heat given off by the gas in a certain time is so greatly in excess of that required to heat up the vessel itself, apart from the contents, that any difference of conducting capacity of the material is negligible. Fireproof earthenware vessels answer admirably over gas, if

care is taken not to use a burner which concentrates the heat in a small central point. A quite large ring turned low is safest to use with this ware.

Although, of course, a full-sized and properly equipped family gas cooker is desirable for household purposes, a very great deal of good cooking on a "bachelor" scale can be accomplished by the aid of small special fitments to be seen in any gas showroom; or can be done by means of a single burner, and makeshift appliances which any ingenious person can improvise. As there is no need too small, so there is no call in the way of catering too great for gas to meet satisfactorily; only, of course, in the latter case it is necessary to go to the proper quarters for advice in the matter.

Domestic users of gas fires, lighting burners, and cookers are occasionally troubled—especially during war time conditions—with "popping" flames, which in severe cases "light back" to the Bunsen nipple, and cannot be relighted in the normal way. The cause of this, apart from insufficient gas pressure, which is plainly to be distinguished, and can only be remedied by addressing a complaint to the gas office, is a change of composition of the gas which renders it incapable of taking so much "primary air"—the air which goes in by the gas nipple and mixes with the gas before its ignition—as usual. It is a question of exigency of manufacture, and shortage of raw material, to which the British gas industry and its customers have happily been strangers. The remedy is to restrict the inflow of primary air, by partially covering the opening in the Bunsen tube, until the flame works in the normal fashion.

Gas cooker ovens may fail on occasion to get sufficiently hot, for no apparent reason. Inspection will usually reveal absence of the proper "dripping pan"

which should close the oven bottom. If this is not the cause of trouble, and the complaint becomes chronic, possibly the apparatus is standing in a through draught; or it may be of defective design, being too open at bottom for the gas of the present day, which usually requires less air for combustion than the heavy expensive supplies of some years ago. The flue outlet from the oven must never be interfered with.

Gas hot-water apparatus is exceedingly convenient, but needs careful handling, to avoid waste. Many prefer the "geyser" for hot baths on this account, because it is not likely to be used unless really wanted, and must be shut off at the proper time. This form of hot-water apparatus is, however, only adapted to the provision of warm baths. A large requirement of hot water for "washing up," and other kitchen uses can only be conveniently provided by the application of gas to the existing "h. and c." circulating system, usually deriving its heat from a boiler attached to the coal kitchener. This arrangement is frequently both inefficient and extravagant of fuel. When contemplating the supplementing of the kitchener boiler by a gas-heated boiler, of which several very efficient kinds are available, the householder will be well advised to have his existing circulatory hot-water pipe system inspected by a competent person, and any defects remedied.

A good deal of mystery attaches, for the ordinary householder and his wife, to the hot-water apparatus that forms part of the house fixtures. So long as it functions fairly well it is usually taken for granted; but a sharp frost, persisting for two or three days, commonly brings the whole thing into particular notice —first, by the stoppage of the flow of water, and when the thaw comes, by its undesigned appearance in inconvenient places. It is no small recommendation

of a good gas-heated system, that with it frost need not be feared.

All domestic hot-water circulating systems comprise the three essential elements of boiler, storage tank, and piping. Frequently an unsatisfactory service is attributable to the boiler, which may overheat the water when the kitchener fire is made up for cooking, or fail to heat it sufficiently at other times. Boilers require cleaning out at least once a year, and oftener in districts where the water is very hard. A loud bumping noise when the fire is burning strongly is the warning that the outlet flow pipe from the boiler is partially choked with deposit. Water should never boil in a closed pipe system, as the deposition of hard lime salts is thereby greatly increased.

The storage tank is often wrongly placed and badly connected with the piping. When this is the case, as expert advice will indicate, it is vain to think of gas heating until the defect has been remedied. The general idea of such a system is quite simple: the cold-water feed, kept at a constant height (or head of pressure) by means of the house cistern, fed from the main through a ball-cock, starts from the highest point, and goes as directly as possible, with a constant fall, to the lowest point of the system. By no means must the inclination of the pipe be reversed, so as to form an "air trap" in this course. The outlet flow pipe from the boiler leaves it at the highest point; and as closely as possible to the boiler should be the storage cylinder, which is in principle merely an "aneurism" on the "flow" pipe. From the top of the storage cylinder rises the hot-water flow pipe, to which all "draw-offs" are connected, which is carried to a point well above the topmost level of the cold feed, where it is left open —being in this part termed the "expansion" pipe.

This is known in the trade as the " single pipe " system, and it is the most effective. In many houses fitted with a hot-water system of long standing the storage element is a " tank," high up in the system, which is less efficient for many reasons. Dissatisfaction frequently results from applying gas heating to an old and defective circulating system of this character.

One valuable feature of a gas-heated water circulatory system is the possibility of regulating the temperature and governing the gas consumption by the agency of a " thermostat." This is a mechanical device in which the temperature of the hot water at the desired maximum—say, 110° Fahr.—is caused to expand a rod or other attachment of the gas valve so as to reduce the supply to the burner. Not only does a good thermostatic control ensure the maintenance of the whole contents of the hot cistern at bath temperature for a small consumption of gas; but it also prevents any possible overheating of the water, at the risk of scalding the user, which is an important safeguard for public baths, hospitals, etc.

The services of town's gas to public safety are considerable. Since the general introduction of the " slot " meters for small consumers, the consequent displacement of petroleum lamps by gas has considerably reduced the number of fire accidents to persons and property. Gas in occupied buildings, large or small, reduces the general risk of fire. If a fire occurs the ordinary supply of gas cannot contribute seriously to the conflagration, even when the main cock cannot be turned off.

Private consumers should not follow the antiquated practice of shutting off the gas at the meter the last thing at night. It deprives the inmates of gas light in an emergency, and increases the risk of explosion

due to escape of gas next day from burners omitted to be shut off by reason of the stoppage of the supply. Actual danger from gas may proceed from two grounds—explosion, or asphyxiation, including poisoning.

If a smell of gas is noticed outdoors, the gas office should be rung up forthwith and notified of the fact. If indoors, however slight the unmistakable odour of an escape, its origin should be sought immediately by smelling, *never with a light;* all windows being meanwhile opened wide, top and bottom, and doors also. Remember that gas, being lighter than air, rises to the ceiling, so that in a closed apartment the dangerous mixture of gas and air may be present in considerable volume overhead before it is noticeable at the breathing level. Although the sense of smell is the best means of warning of a gas escape, this sense varies greatly in acuteness in people, and may be almost deadened in the aged, and as an effect of a cold in the head. A person coming in from the fresh air will usually detect the smell more quickly than one who has perhaps been engaged in cooking. A sleeping person may not be awakened by a really dangerous proportion of gas in the atmosphere, which would certainly alarm anyone fully awake.

Unless the source of the escaped gas happens to be a broken street main from which the gas filters into an adjoining basement, it must be traceable to a tap left open with the burner unlit, or to an old-fashioned "hydraulic" pendant having dropped. These should be made safe or done away. It is not difficult even in the dark to feel for the tap of any gas fixture, and so ascertain if it is turned on. No tap which goes all round should be sanctioned. Gas cooking stoves are sometimes sinners in this respect, and are the more

likely to be responsible for escapes where children can get at the taps.

In the event of a person being overcome by inhaling escaped gas, he should be removed into the open air and laid upon his back with head slightly raised, and all tight clothing loosened to allow of artificial respiration being vigorously applied. Medical aid should, of course, be summoned; and, if possible, an oxygen bottle procured at a druggist's. The gas office should be called up, as they generally have in readiness all the necessary remedial appliances.

THE END

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